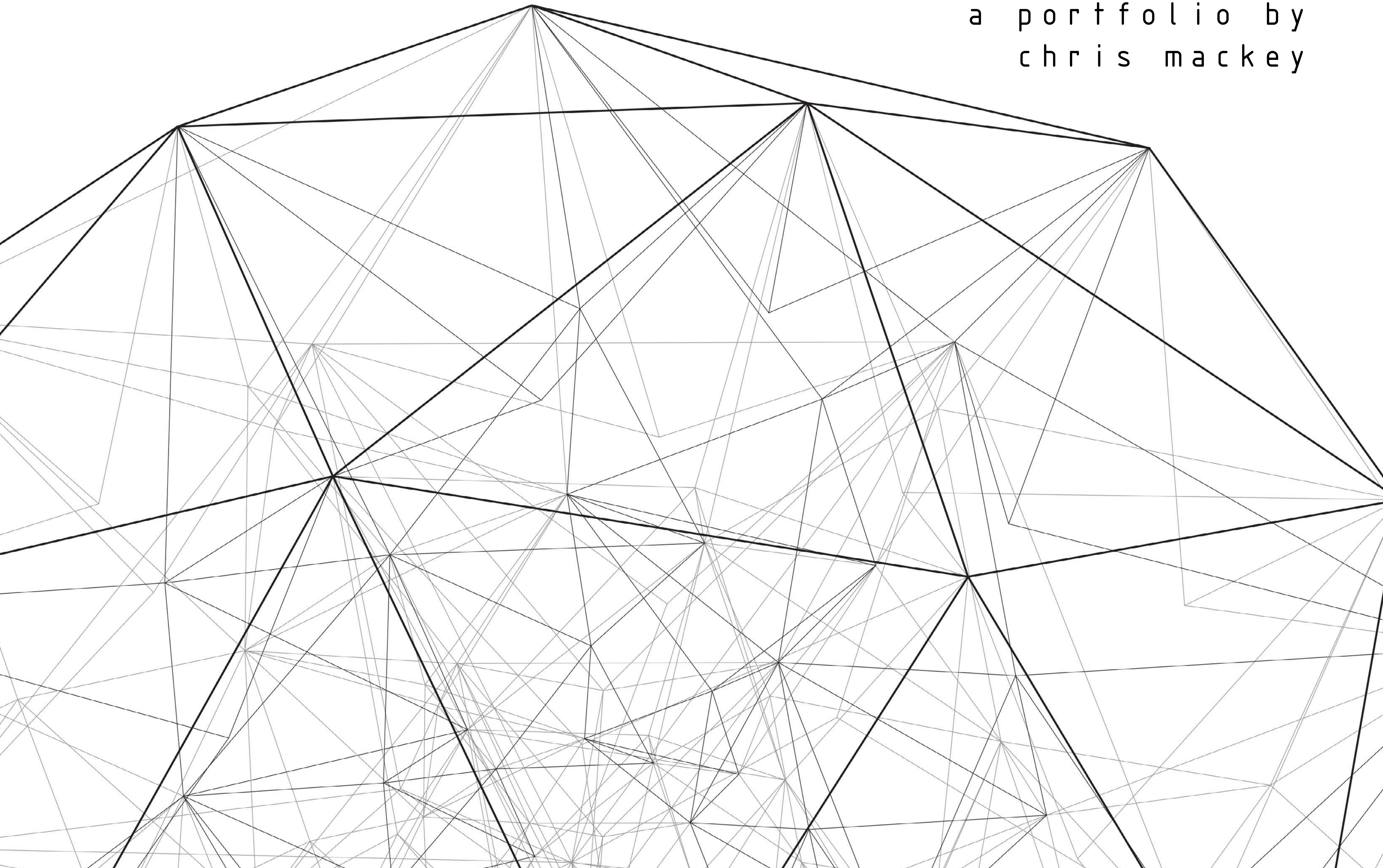
thermo-dynamism

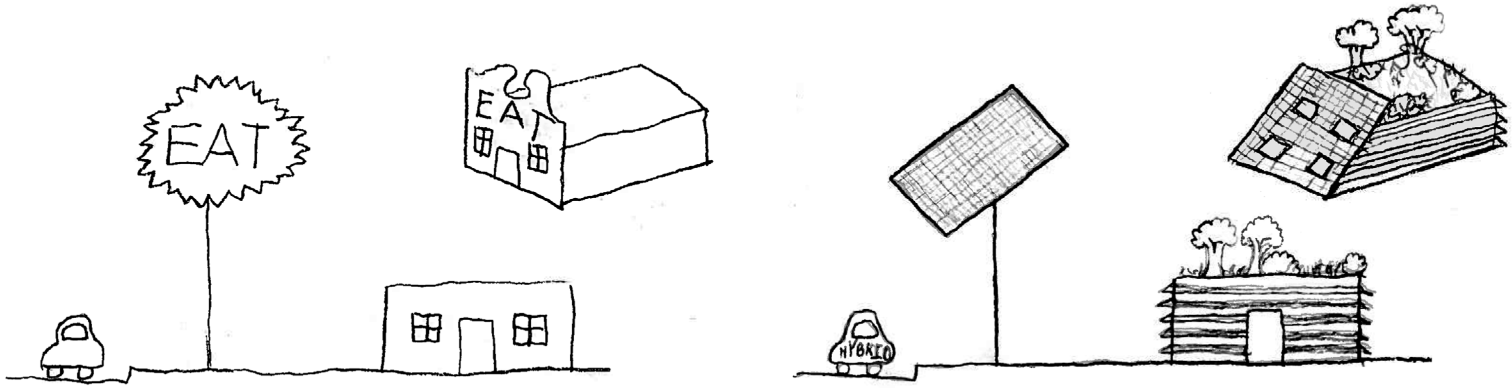
a portfolio by
chris mackey



author

Chris Mackey is a graduate student at MIT who is currently pursuing a dual degree for a Masters of Architecture and a Masters of Science in Building Technology. With an expected graduation date in Spring 2015, Chris is currently working towards a combined thesis between these degrees, which will focus on thermally adaptive occupant behavior and the design possibilities presented by occupants moving around a space to make themselves comfortable. His work experience has ranged from being a climate researcher at Yale University, to a designer at an architecture firm, to an energy modeler and software developer. In his free time, Chris is an avid coder and contributor to the open source Ladybug + Honeybee environmental analysis plugins for grasshopper and is in the process of adding several new tools to the suite that will allow for the study of in-depth thermal comfort.

t h e s i s



As the architecture profession hurdles into a period of “green” building, many architects, clients, and now even the public at large are becoming aware that much of the “green” aesthetic that is marketed towards them is largely superficial with little-to-no real environmental benefit arising from their decision to live in a given “green” building. The realization of the superficiality of “greenness” has manifested itself in the term “greenwashing,” which broadly describes the marketing frenzy that has managed to label products as environmentally detrimental as bottled water somehow magically safe for consumption without consequences. Greenwashing in the architectural profession has frequently been used to describe elements such as green roofs, living walls, photovoltaic panels and other superficial elements that only coat the surface of a building and communicate nothing about the deeper thermodynamic workings and far-reaching environmental impact of the building. Among the examples of today’s green architecture, there is a sense that this trend, which parades as a new revolutionary movement, is nothing more than an echo of the previous postmodern movement. The green roofs, living walls and solar panels are nothing more than mere billboards broadcasting a 24/7 television show called “I’m Green” to a public of docile consumer/viewers and architects are simply enablers of this increasingly fragile consumption-based system that draws us closer to energy insecurity, global resource instability and climactic ruin.

It is it precisely because of this passive, consumer-oriented attitude that our crises of energy and climate persist. On every level of the industry, from the design process through construction all of the way to occupation, we view human beings simply as passive receivers of materials, information and conditions as opposed to active participants within our contemporary architectural system.

Occupants in both architectural models and building energy models are viewed respectively as passive consumers of the visual medium of architectural objects or fixed heat sources with static thermal preferences that simply “consume” the product of air conditioning. The complex dynamism of real-world human activity and metabolism is ignored as the profession refuses to see occupants as participants who open windows, draw shades, move around a space, change the appearance of it, and alter their local environment to suit their needs. Similarly, outdoor climate, even in the “greenest” of contemporary building practices, is still often viewed as something that merely happens to our buildings rather than a resource of heat sources and sinks that our buildings help shape through the interaction of different material and energetic forces. If continued, this view of climate as a harsh, unalterable, external force from which a building must isolate or insulate its occupants will lead to the actual manifestation of outdoor climate as such. Lastly, when it comes to viewing the material palette of our buildings, we almost always passively accept the seemingly ubiquitous concrete, steel, glass, and insulation products without seeing the near-infinite chemical potentials in the resources around a site. Content to simply minimize the quantity of these expensive, foreign "site-less" materials by small margins, we ignore the potential of buildings to reinforce local economies and, in this paradigm of ever lighter buildings, miss out on the enormous potential offered by thermal inertia.

Accordingly, instead of appreciating the complex interactions between occupants, climate, and materials that are almost always given in any architectural setting, we are content to simply take an additive approach, seduced by new foreign products and gadgets that we simply throw into our wasteful architectural contraptions to further complicate the problem. Our few attempts to synthesize these three very complex phenomena occur almost exclusively in mathematical matrices of computational energy models, which, after pulling these three terms together through the universalizing first law of thermodynamics, simply spew out separate streams of numerical data. We rarely take the extra step of integrating these separate streams of data into visual formats that can be understood and interpreted by humans, inducing the much more important synthesis in the minds of a design process's decision-makers. As such, our current computational tools, which have the power to inform us of these three incredibly complex phenomena, remain merely analytical, passively accepting a set of conditions as inflexible. It is rare that such tools cross over to the stage of being instrumental, attempting to actively inform and influence the design process.

This rejection of the passive, consumerist, analytical attitude that threatens to overcomplicate and paralyze advancement on energy issues, and engagement with the complex energy flow through occupants, climate and materials with the aim of informing and bettering the overall system shall henceforth be referred to as thermo-dynamism. This term implies a re-definition of the contemporary human being in relation to the larger material/climatic/social system to which he or she belongs. No longer should we see humans simply as over-specialized cogs in an overcomplicated social contraption, consuming resources and performing the same mechanical task over and over again. As concentrations of high-grade energy, humans must now fulfil an important dynamic function to not just consume resources but to feed back to their parent system, changing it and strengthening it through application of their own knowledge. This feedback can occur in a multitude of ways, whether it be through education with an open source software movement (such as one to which the author contributes), through the supply of educated and informed decisions about how to direct the flow of material and climactic resources in design, or simply being aware of energy flow in one's own local environment and taking informed steps to engage and change it to one's own needs.

This book documents the struggle of a design and science research student to follow such a philosophy of thermo-dynamism in his work. It records his emerging awareness of the current ineffective practices occurring around him and details his attempts to inform and change them in a personal struggle to feed back to a larger system. In an attempt to integrate across disciplines and combat the tendency of over-specialization that afflicts much of the present economic system, the work draws on resources in cultural history and social science, the quantitative natural sciences, and physically-based material investigations. These are respectively investigated through the following:

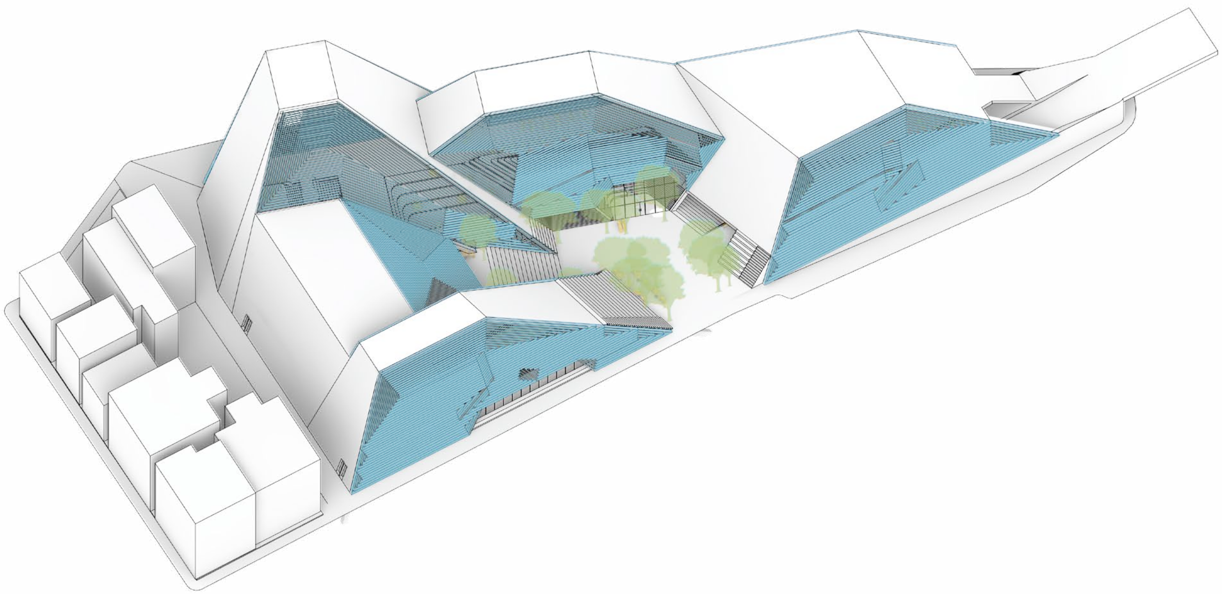
1) The development of fully occupiable architectural designs speculating on potentials of human behaviour.
2) A climatic and natural scientific research effort.
3) A series of parametirc fabrication experiments investigating material properties.

contents

architectural designs

science research

fabrication experiments



architectural designs

urban oasis library

While the rise of digital media and its ability to be taken almost anywhere have changed the usership of today's library, it is important to remember that, though information can now travel anywhere, the process by which information enters the human mind still requires a given set of environmental conditions that are often tied to specific locations. As our culture transitions into the digital age, this currently undervalued role of the library as a provider of conditions for learning and concentration will become more prominent. The once-prominent storage function of the library will shrink to become the (now common) robotically-retrieved book archive and server room, providing the library's learning spaces with not only information but also with heat and thermal mass. Together with these new service spaces, the library of the future will function as one organism to create desirable microclimates for learning and exploration.

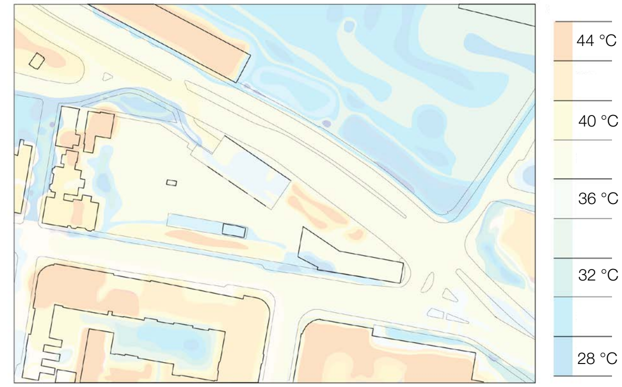
Project Type - Academic
Role - Designer (the only one)
Duration - 5 Weeks
Date - Spring 2012
Location - Downtown Boston

THE SITE - THE URBAN DESERT WASTELAND

Excessive Air Pollution

Map derived from a 2010 report on traffic volume, typical CO concentrations of automobile exhaust, and the Boston wind rose.

Dangerously High Summertime Temperatures

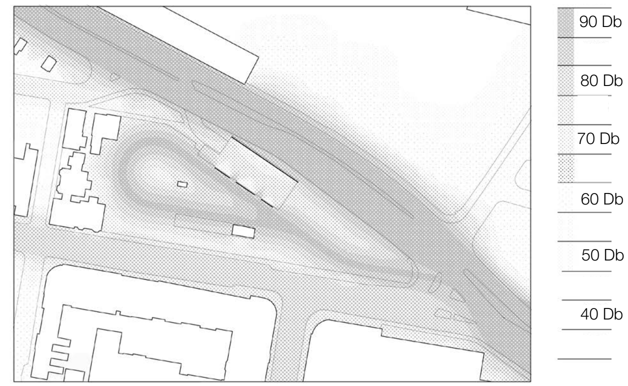


Map derived from LANDSAT 7 surface temperature images enhanced with albedo/vegetation studies of high-res aerial images.

Too Much Direct Sunlight and Glare

Map derived from GIS data on building footprint and height, Boston's sun plot, and the Plugin DIVA developed by C. Reinhart et. al.

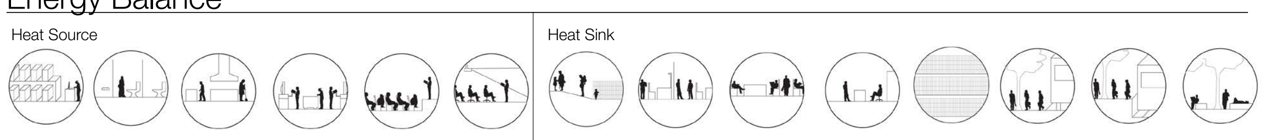
Loud Traffic



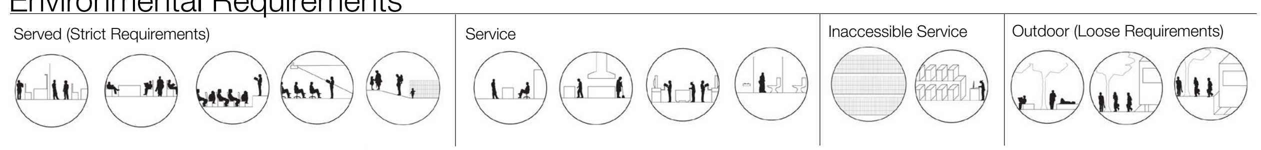
Map derived from a 2010 report on traffic volume, in situ noise measurements, and estimated effects of the building geometry.

THE PROGRAM - THE MICROCLIMATIC RESOURCE

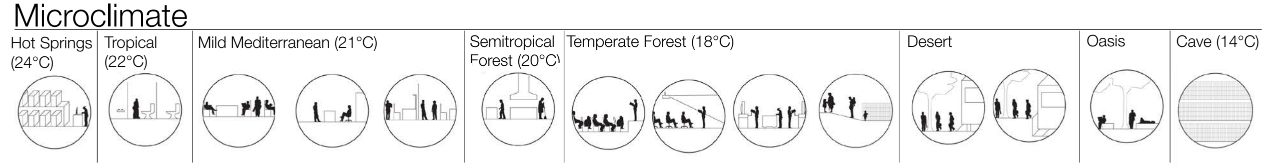
Energy Balance



Environmental Requirements

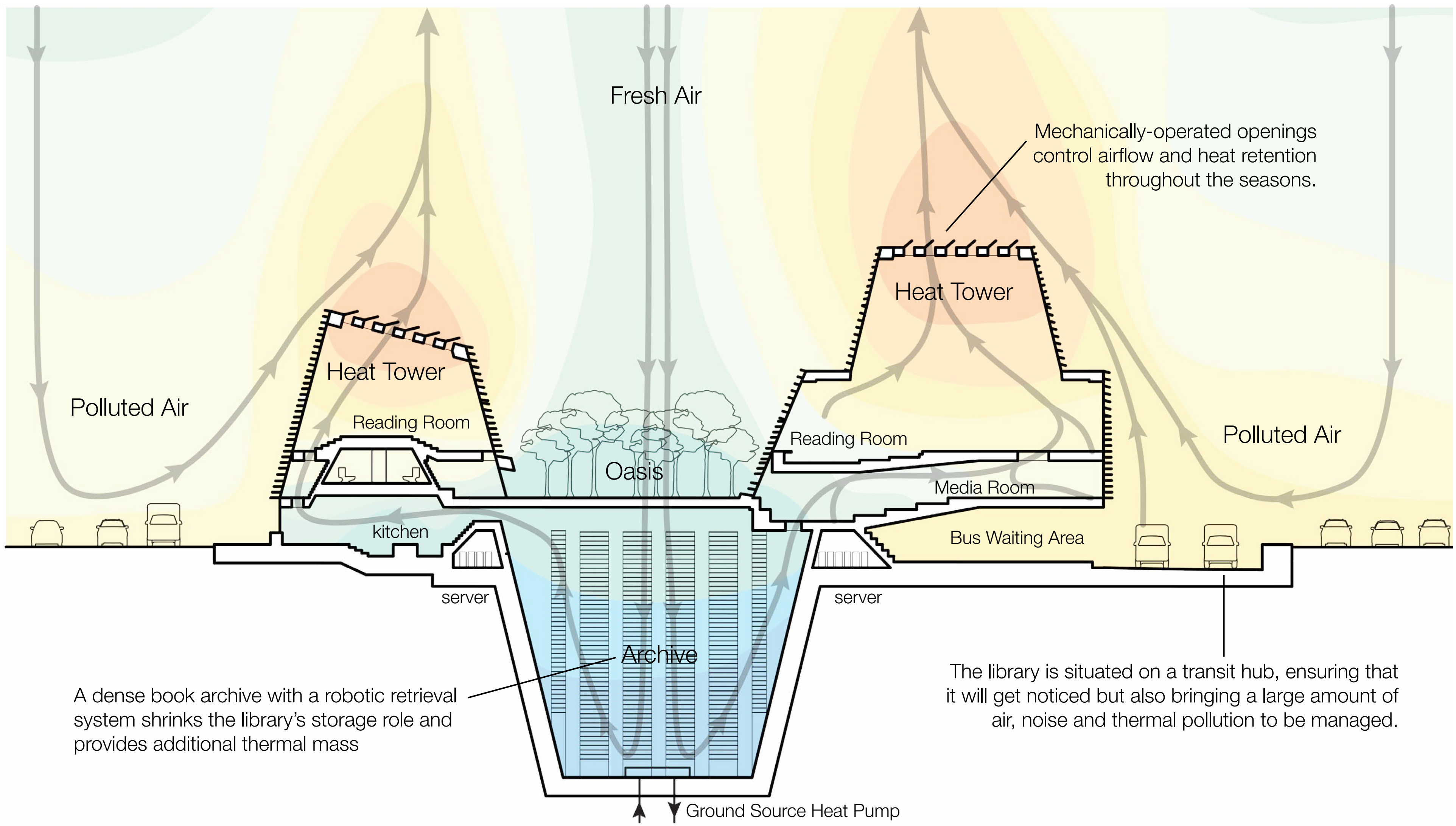


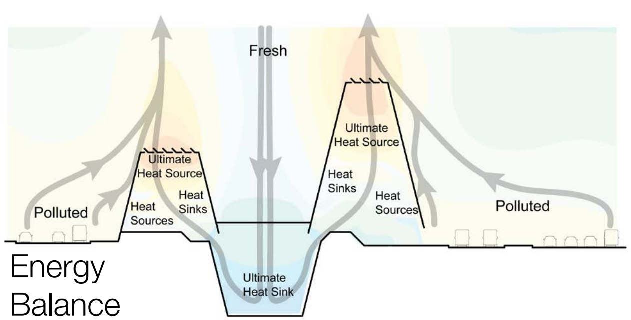
Microclimate

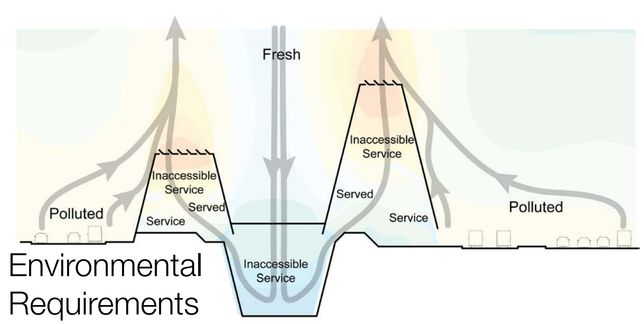


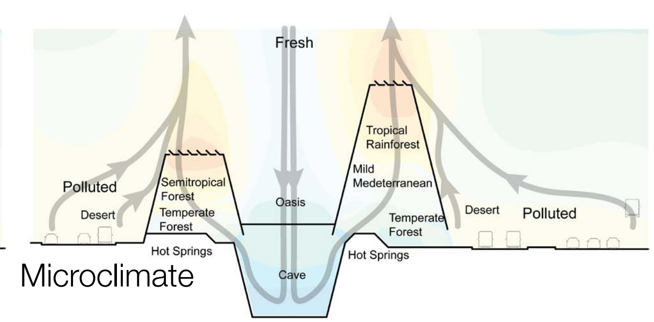
LIBRARY MACRO ORGANIZATION - THE URBAN OASIS

in the digital age, the library’s role as a space for concentration will be one of the few remaining reasons for the building’s continued use, Accordingly, programs are organized to ensure the proper functioning and use of a central urban oasis protected from the pollution, heat, noise, and sun of the urban desert.







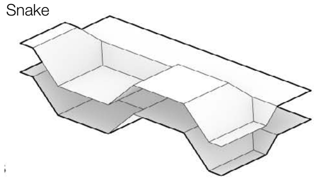


LIBRARY MESO ORGANIZATION - THE FLUID MICROCLIMATIC LANDSCAPE

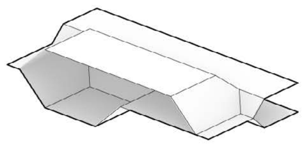
Between the cold basement archive and the heat towers, an undulating wall-less landscape exists with dips and rises corresponding to different microclimates.

Program Organizers

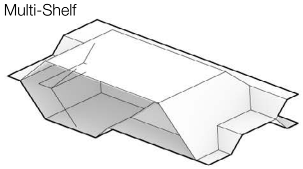
Snake



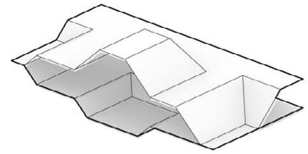
Shelf



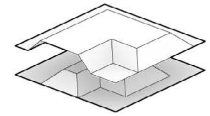
Multi-Shelf



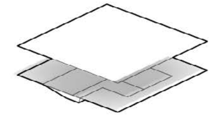
Gradual Expansion



Plinth

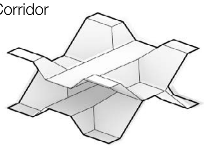


Depression

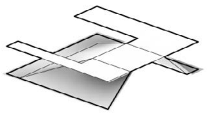


Circulation Organizers

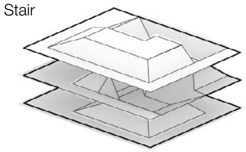
Corridor



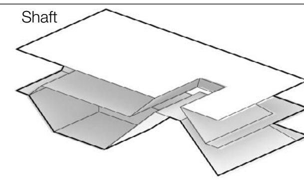
Ramp



Stair



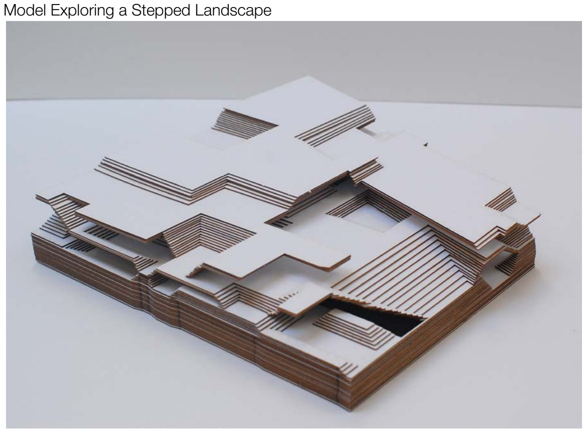
Shaft



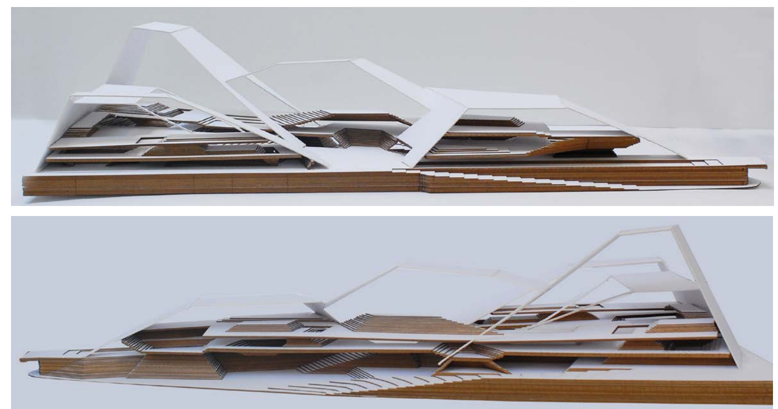
Landscape Models

Initial Microclimatic Landscape Model

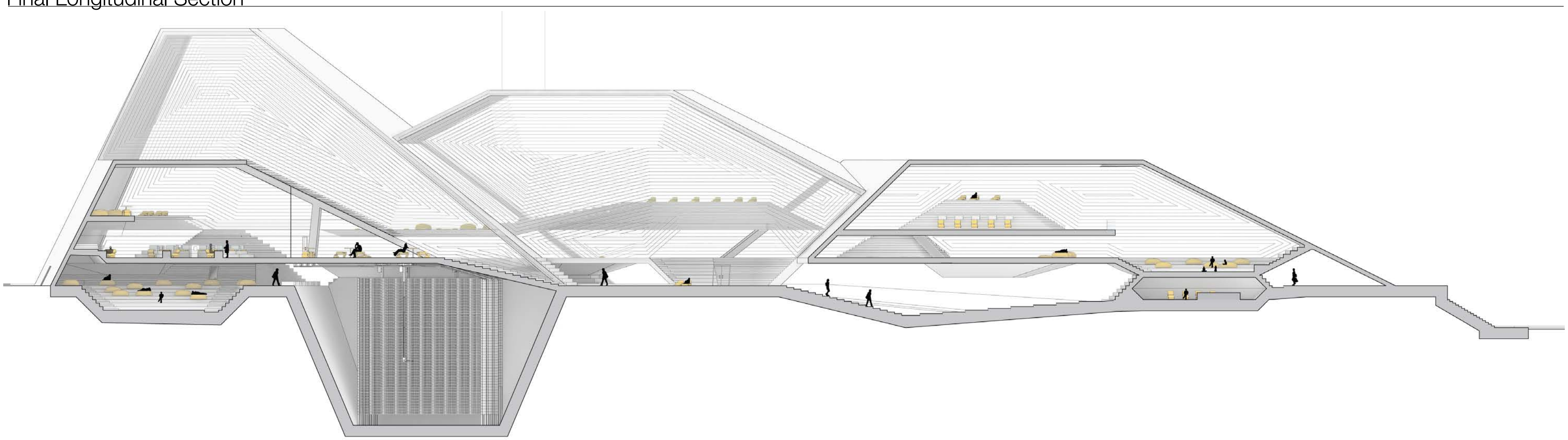
Model Exploring a Stepped Landscape



Final Model

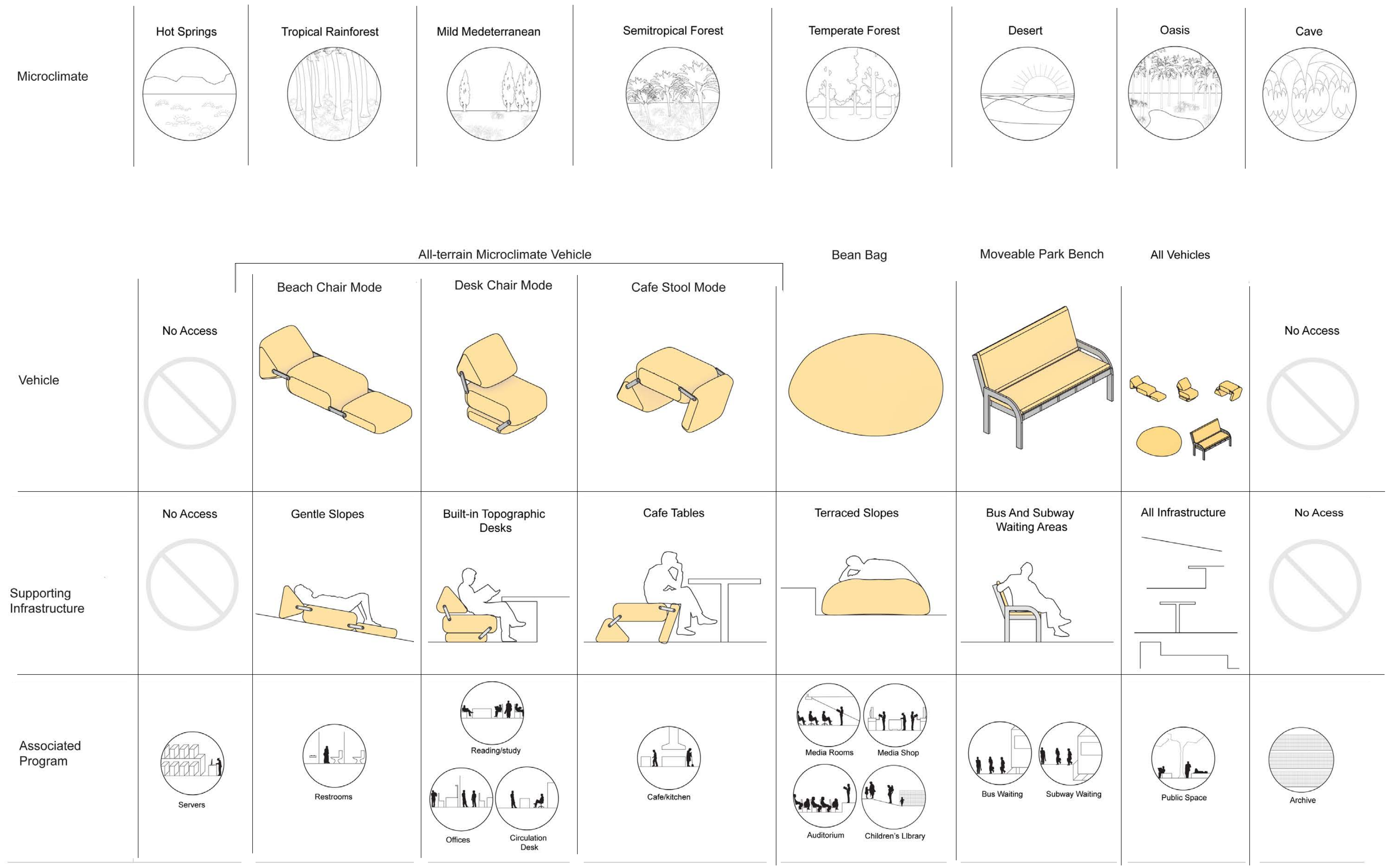


Final Longitudinal Section



LIBRARY MICRO ORGANIZATION - MICROCLIMATE EXPLORATION “VEHICLES”

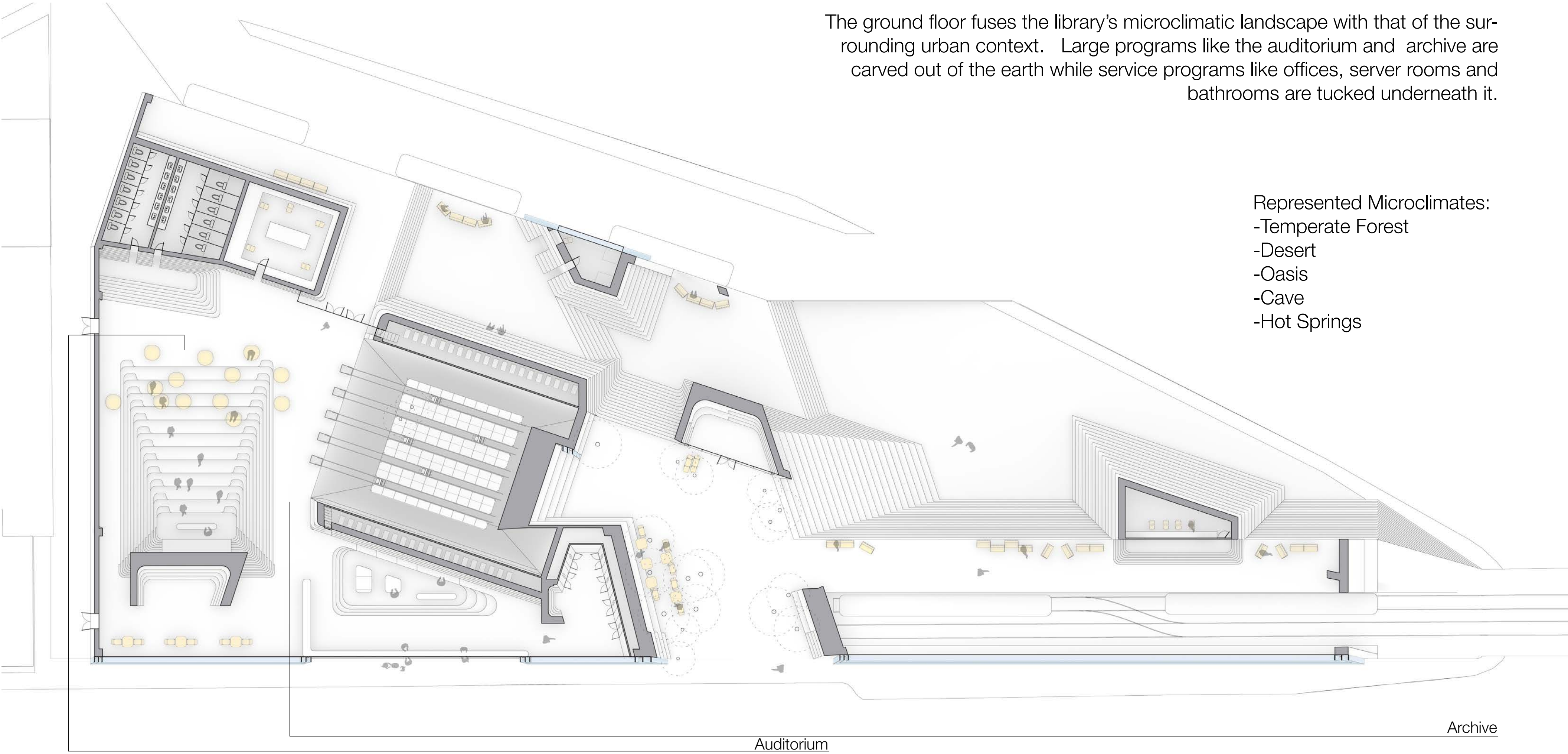
Library visitors are encouraged to move around and explore the microclimatic landscape to find an environment that suits their reading preference. Portable furniture pieces or exploration “vehicles” can be found throughout the library to help users inhabit the spots they prefer.

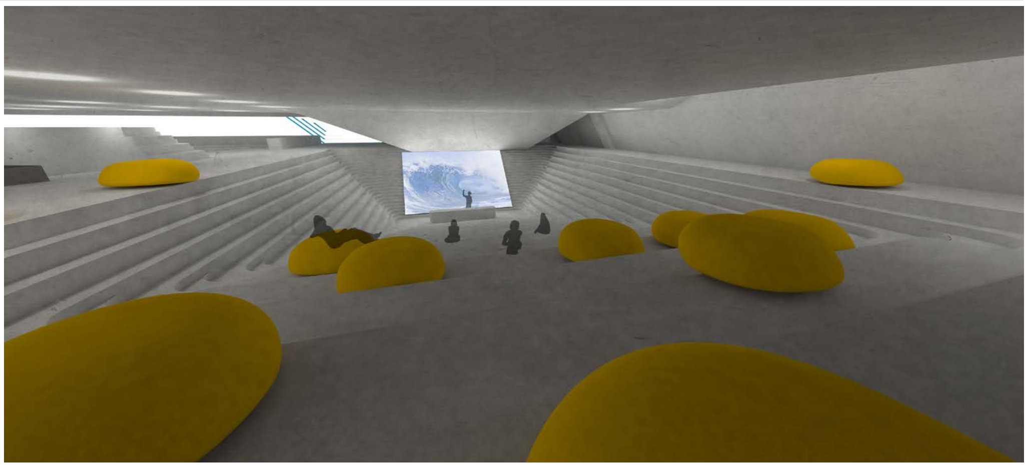


FLOOR 1 - GROUND FLOOR

The ground floor fuses the library's microclimatic landscape with that of the surrounding urban context. Large programs like the auditorium and archive are carved out of the earth while service programs like offices, server rooms and bathrooms are tucked underneath it.

Represented Microclimates:
-Temperate Forest
-Desert
-Oasis
-Cave
-Hot Springs

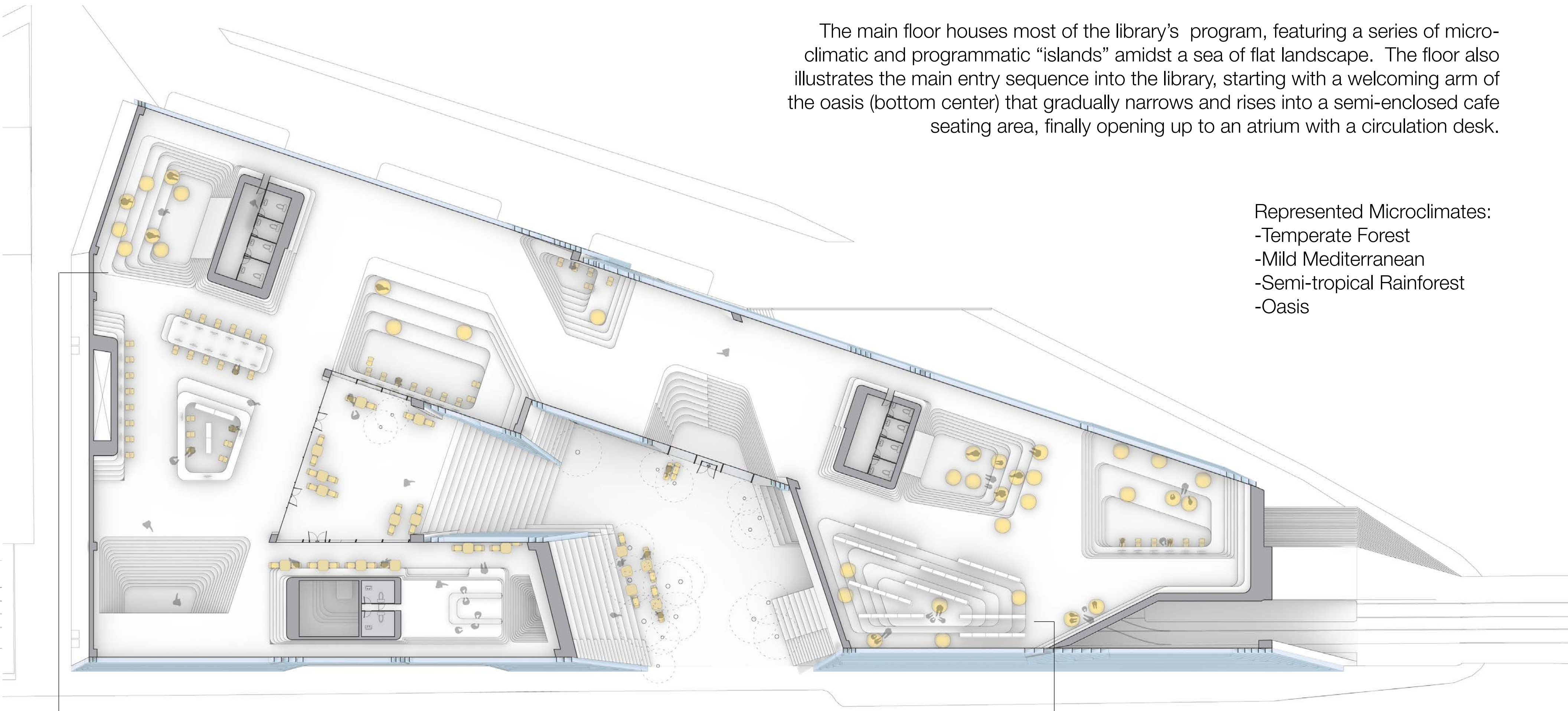




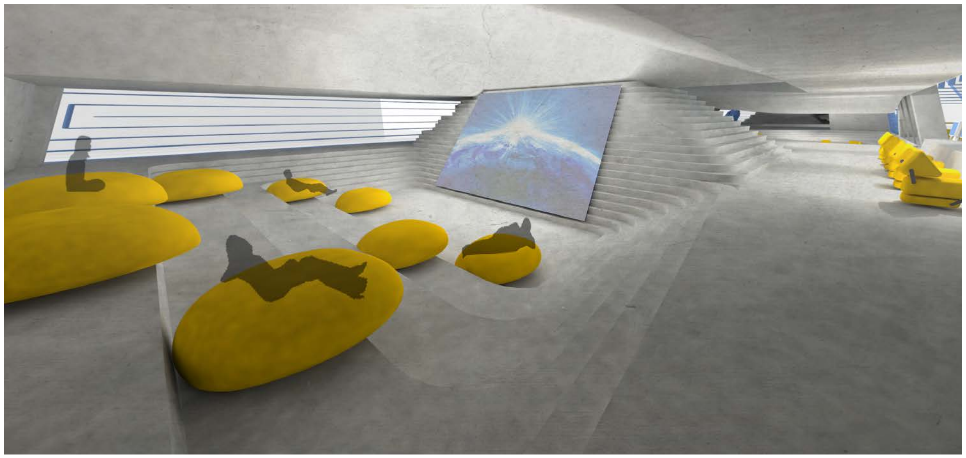
FLOOR 2 - MAIN FLOOR

The main floor houses most of the library's program, featuring a series of micro-climatic and programmatic "islands" amidst a sea of flat landscape. The floor also illustrates the main entry sequence into the library, starting with a welcoming arm of the oasis (bottom center) that gradually narrows and rises into a semi-enclosed cafe seating area, finally opening up to an atrium with a circulation desk.

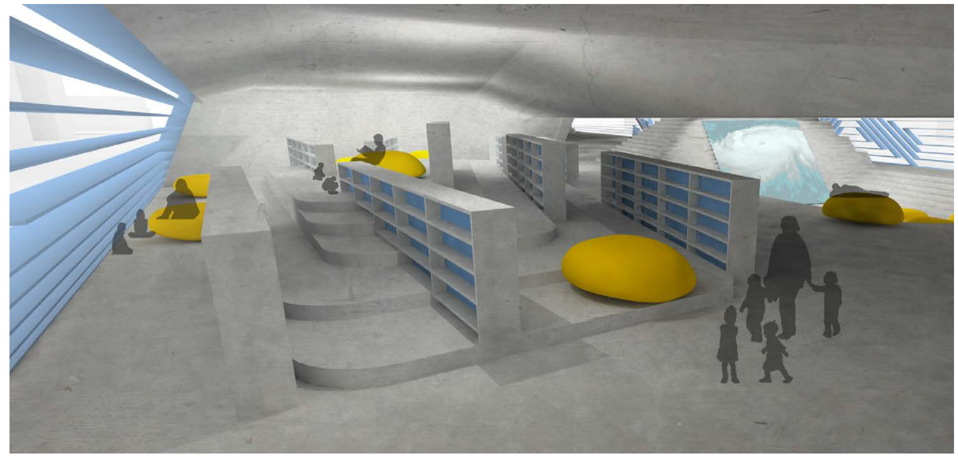
Represented Microclimates:
-Temperate Forest
-Mild Mediterranean
-Semi-tropical Rainforest
-Oasis



Media Room



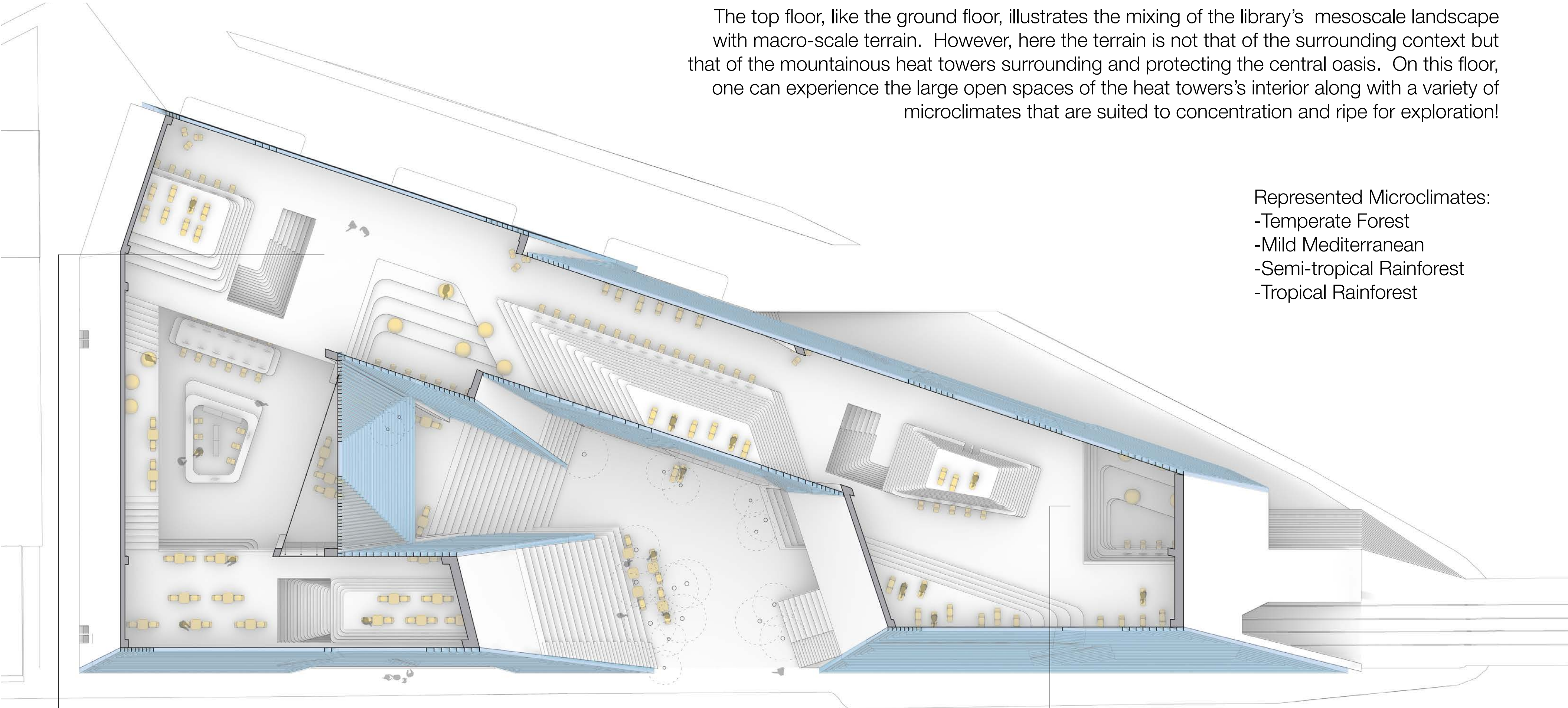
Children's Area



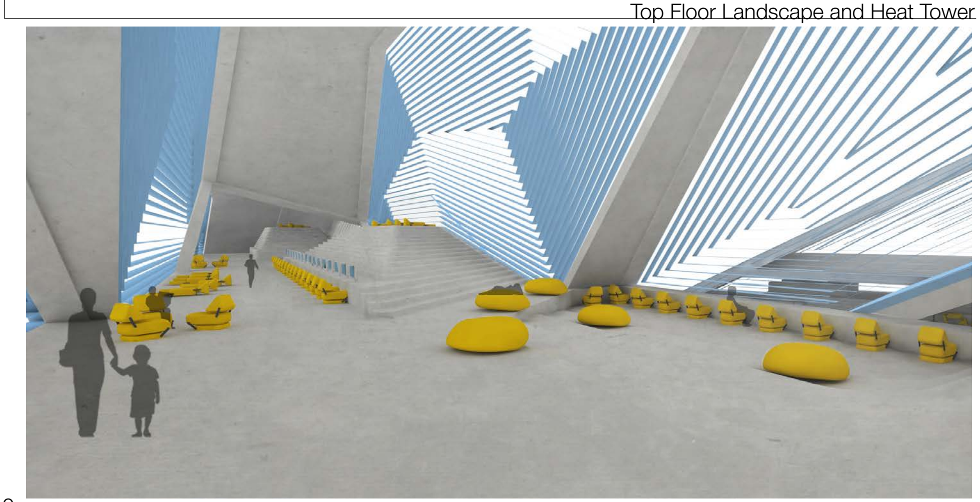
FLOOR 3 - TOP FLOOR

The top floor, like the ground floor, illustrates the mixing of the library's mesoscale landscape with macro-scale terrain. However, here the terrain is not that of the surrounding context but that of the mountainous heat towers surrounding and protecting the central oasis. On this floor, one can experience the large open spaces of the heat towers's interior along with a variety of microclimates that are suited to concentration and ripe for exploration!

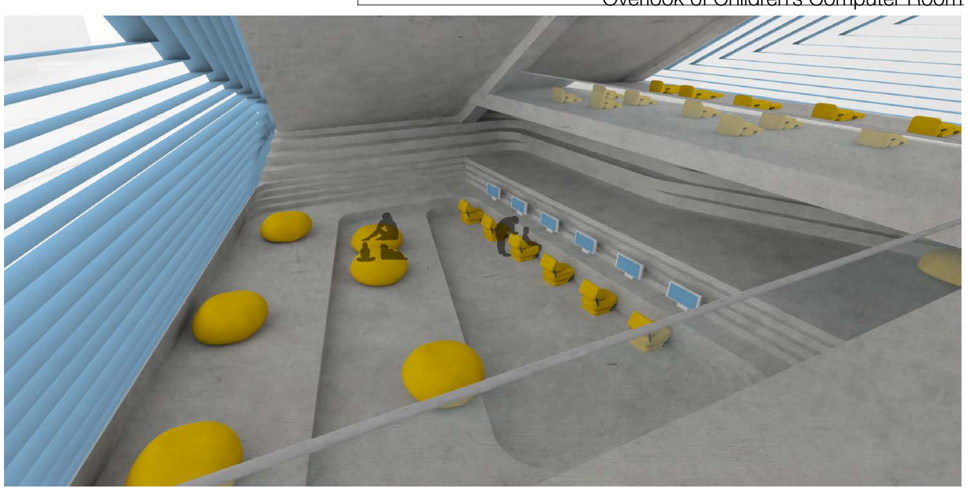
Represented Microclimates:
-Temperate Forest
-Mild Mediterranean
-Semi-tropical Rainforest
-Tropical Rainforest



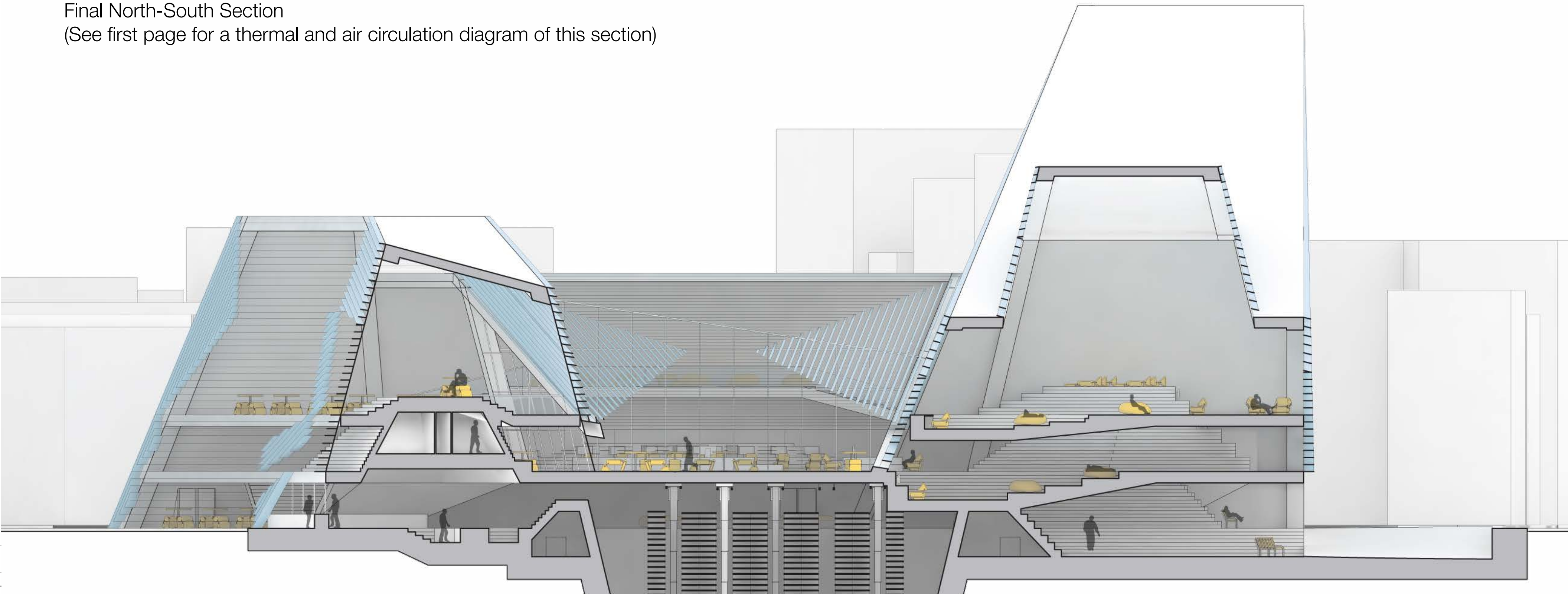
Top Floor Landscape and Heat Tower



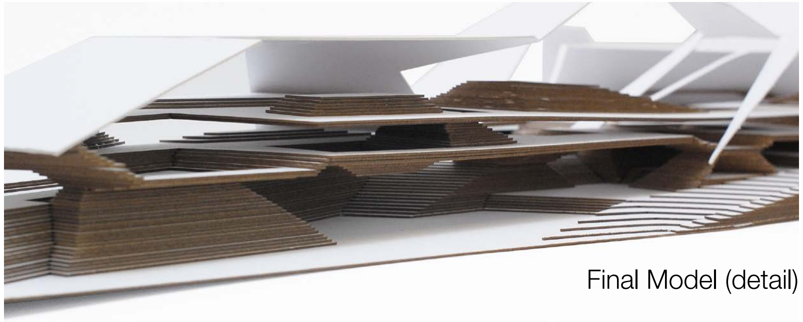
Overlook of Children's Computer Room



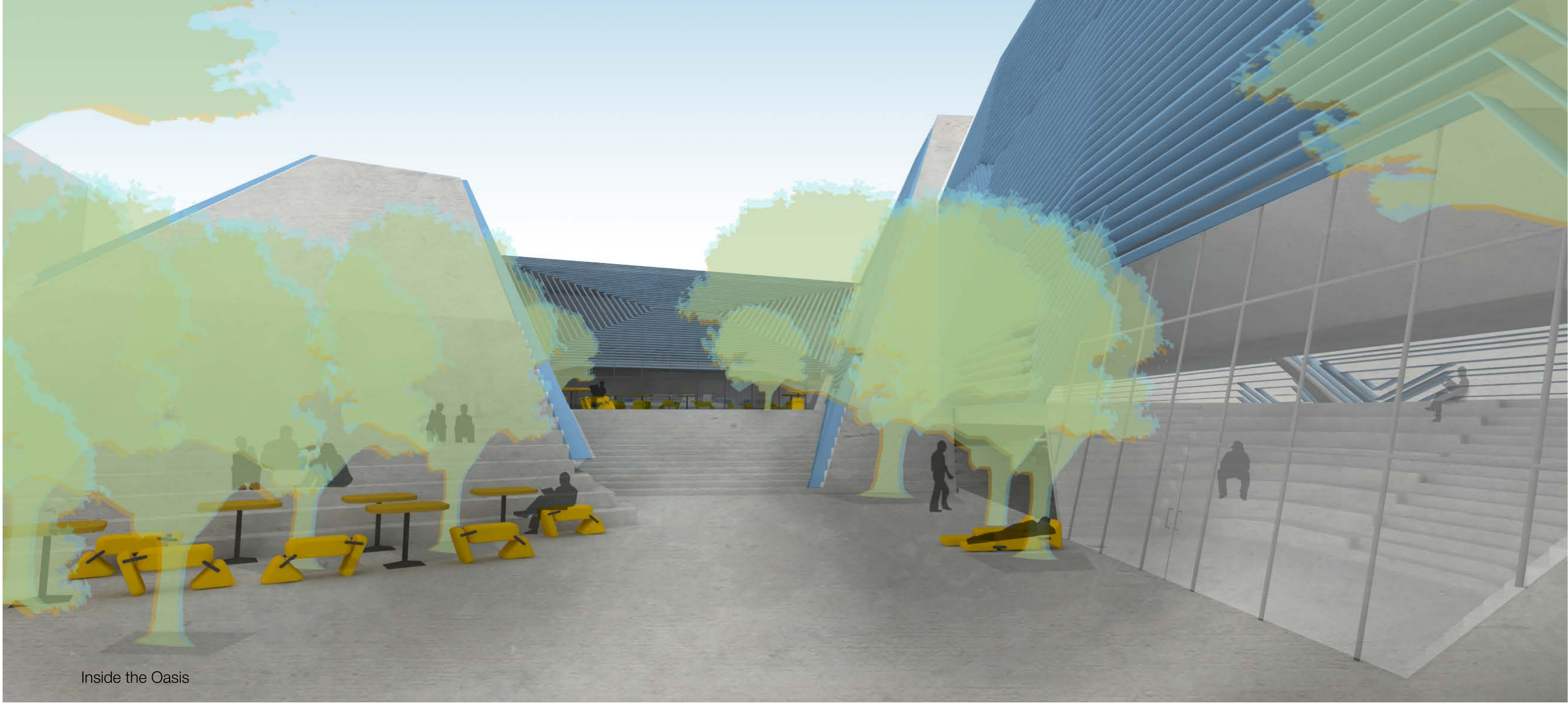
Final North-South Section
(See first page for a thermal and air circulation diagram of this section)



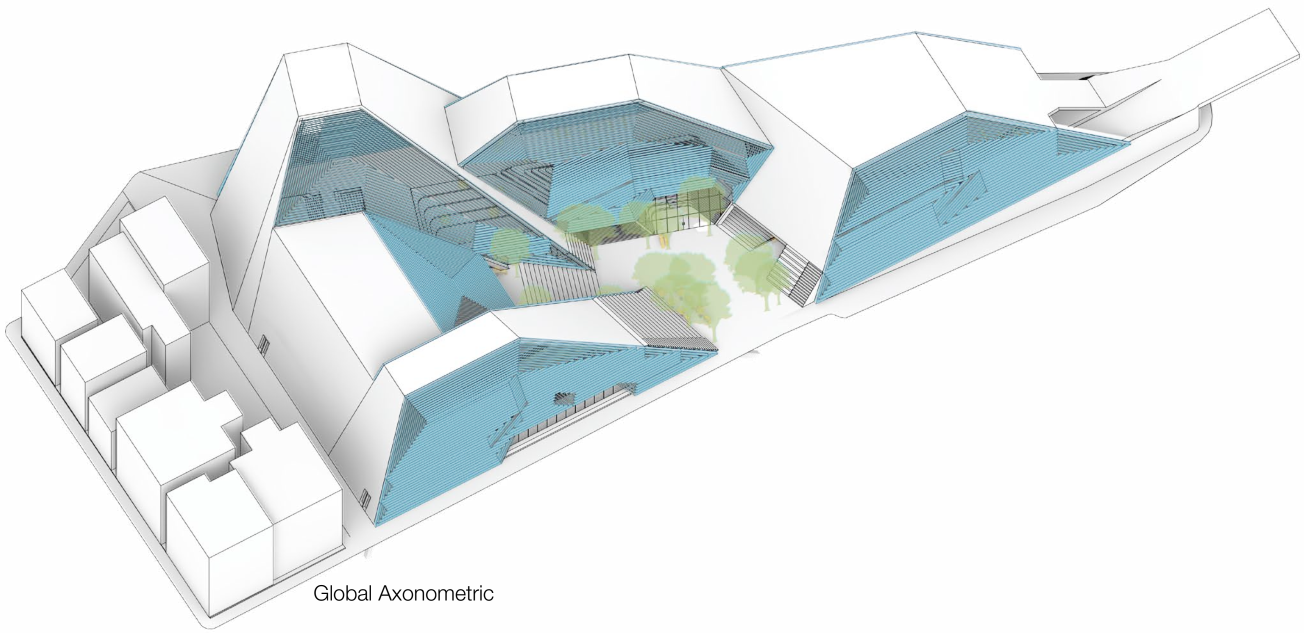
Final Model (full)



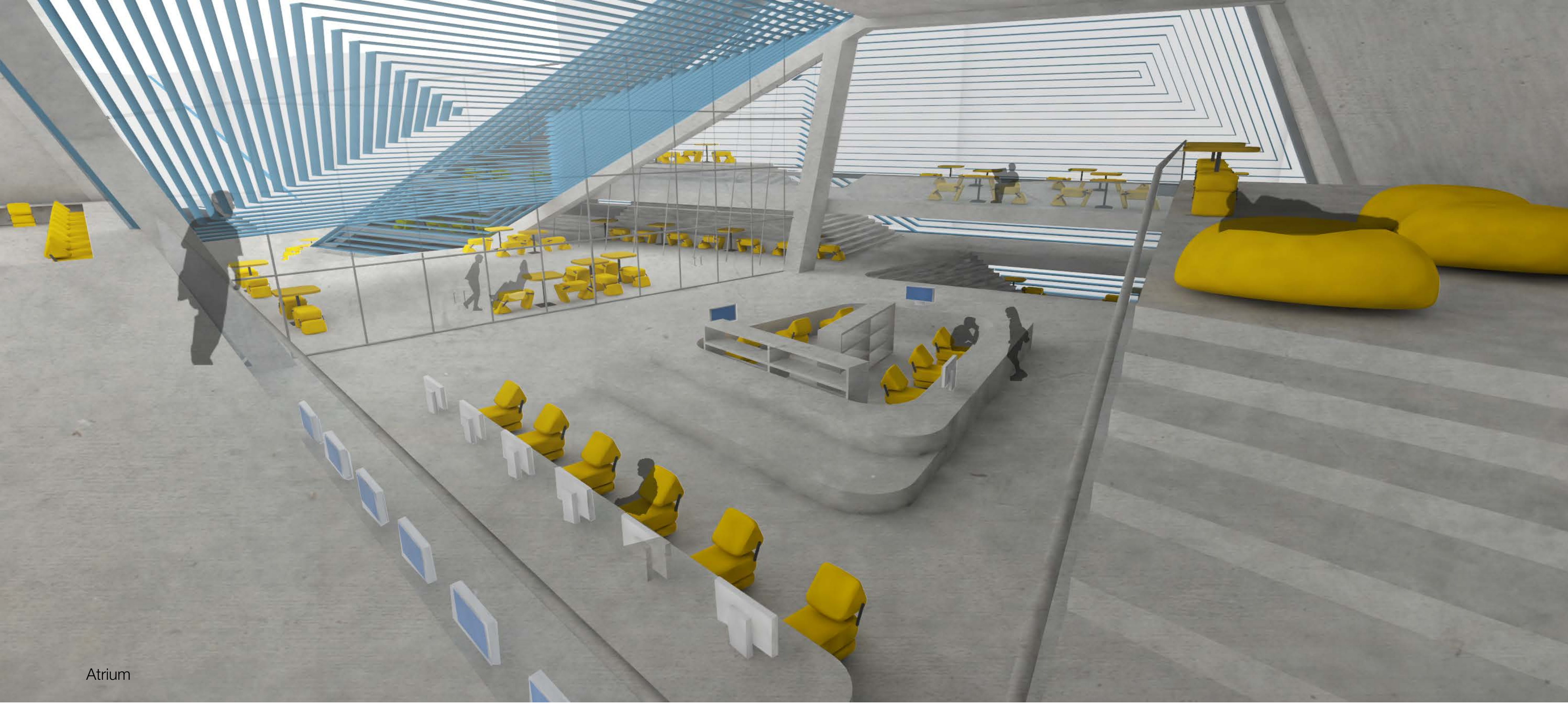
Final Model (detail)



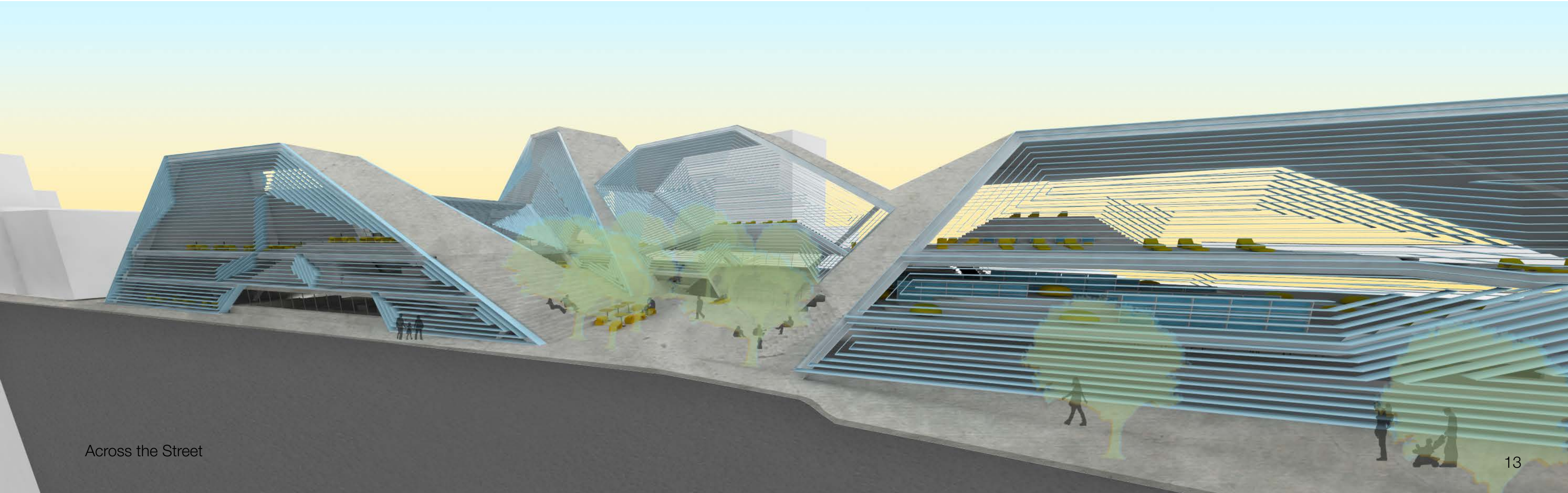
Inside the Oasis



Global Axonometric



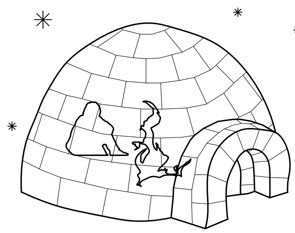
Atrium



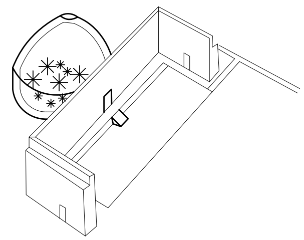
Across the Street

climate pod cinema

Climactic Ideal

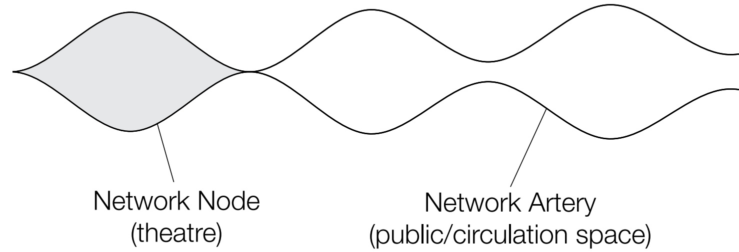


igloo



yakhchal
(ice house)

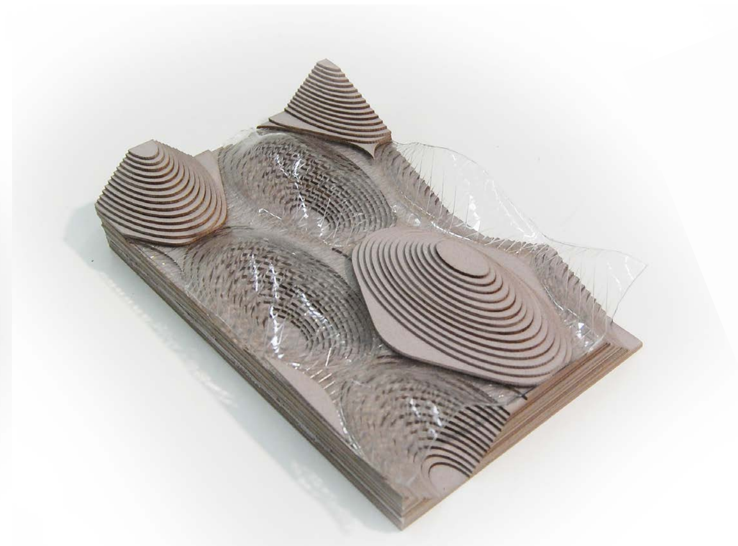
Systematized Climactic Ideal

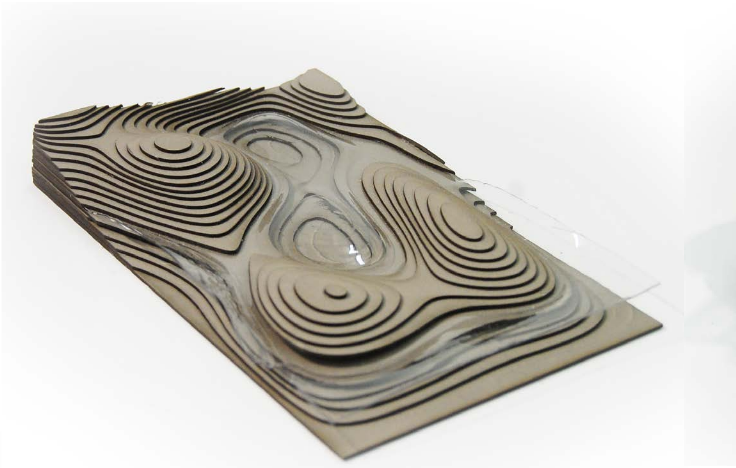


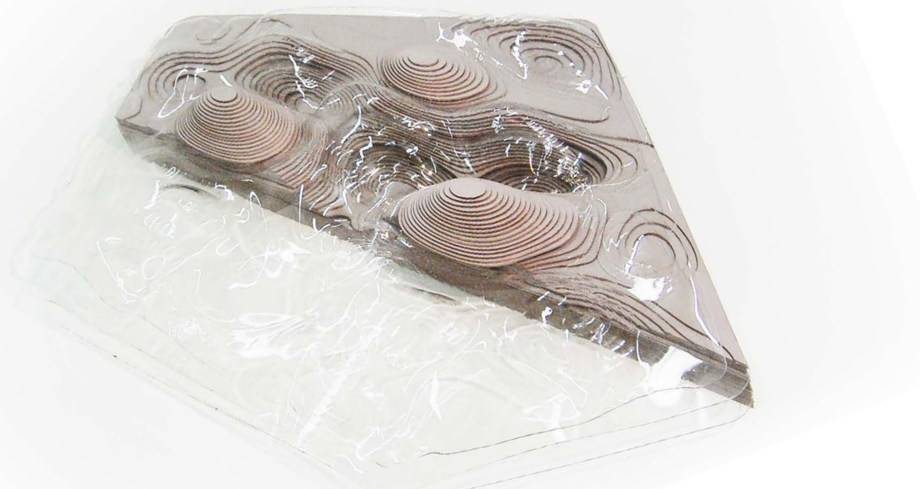
As we move into an age where access to video becomes ever easier and faster, the role of the cinema has been undergoing a drastic change. One way in which the cinema has begun to adapt to this new environment is through the notion of an all-encompassing experience. The IMAX is perhaps the best embodiment of this strategy with features such as 3D glasses, surround sound systems, and (perhaps the most important architecturally) domed screens that give the viewer a sense of enclosure within the movie. Such a domed arrangement of the cinema also holds great potential for an additional level of an all-encompassing experience - the thermal. The dome's geometry is ideal for shaping a temporally varying climactic experience since it has minimal losses to the exterior given its smaller surface area.

While the dome holds many potentials to further engulf the viewer's thermal experience, it presents many architectural challenges, especially in an urban context where real estate is valuable and it is often desirable to stack program. This project explores the potentials of such an arrangement of climatic domed spaces.

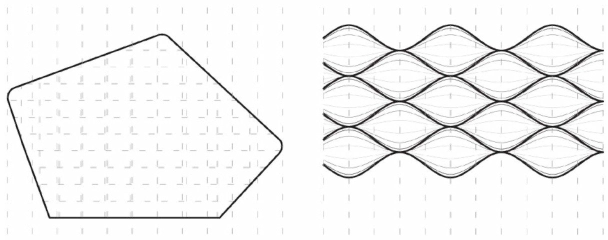
Project Type - Academic
Role - Designer (the only one)
Duration - 8 Weeks
Date - Fall 2011
Location - Downtown Boston



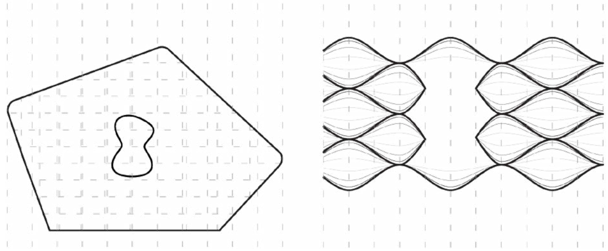


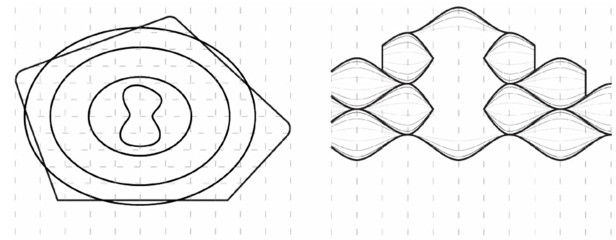
Step 1:
Set upper, lower, and horizontal limits on the system. Here, these are the limits of the site and a height of 5 stories.



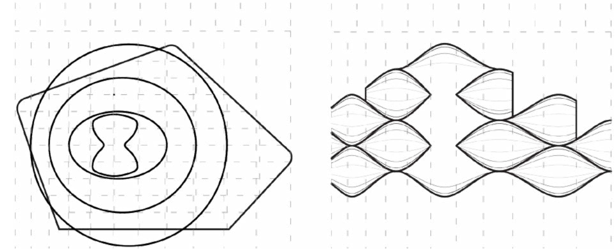
Step 2:
Carve out a vertical circulation space in the center of the site through which visitors must pass for ticketing.

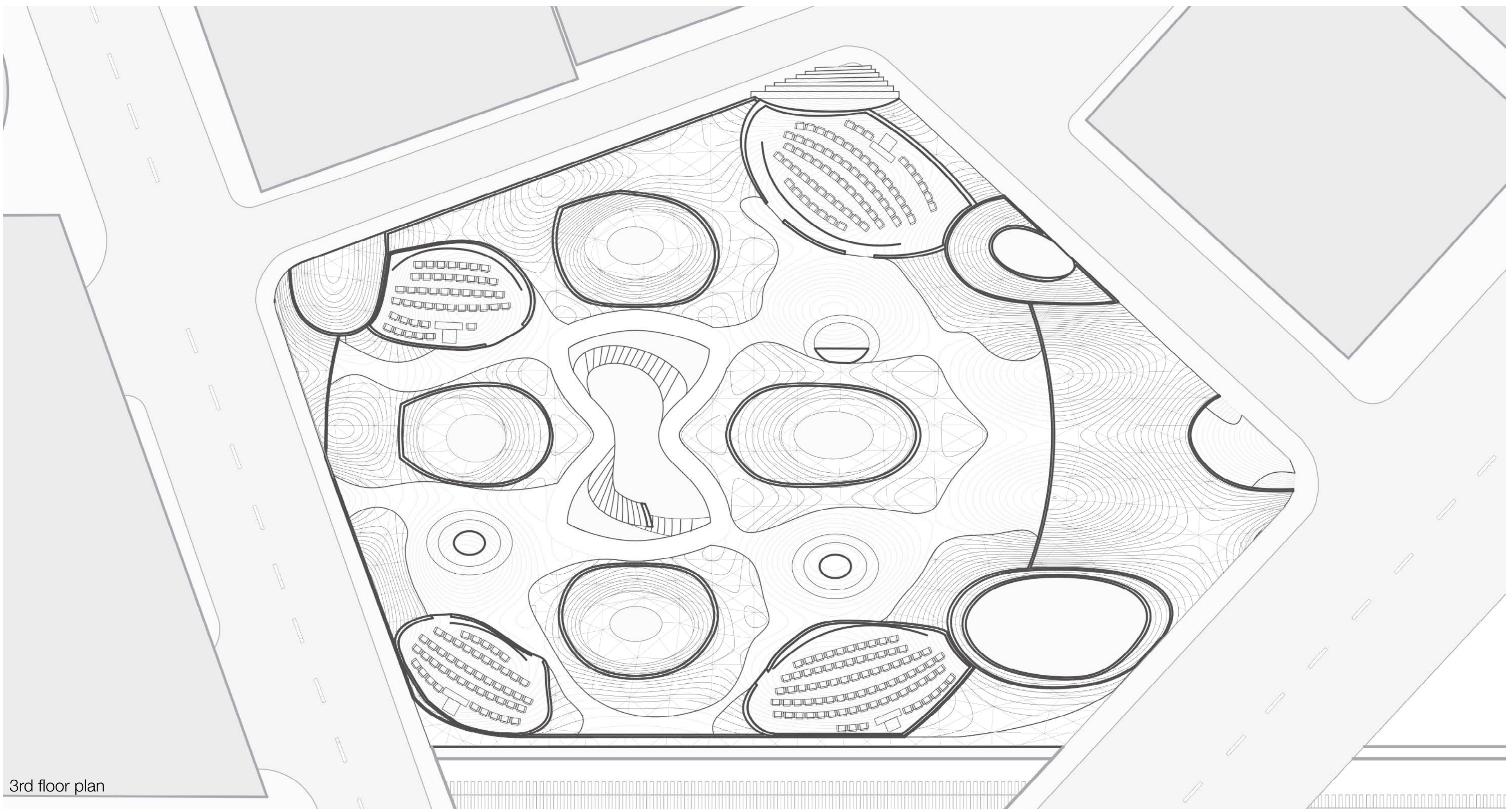


Step 3:
Trim the edges of the system with a setback plane to allow for different levels of natural light.

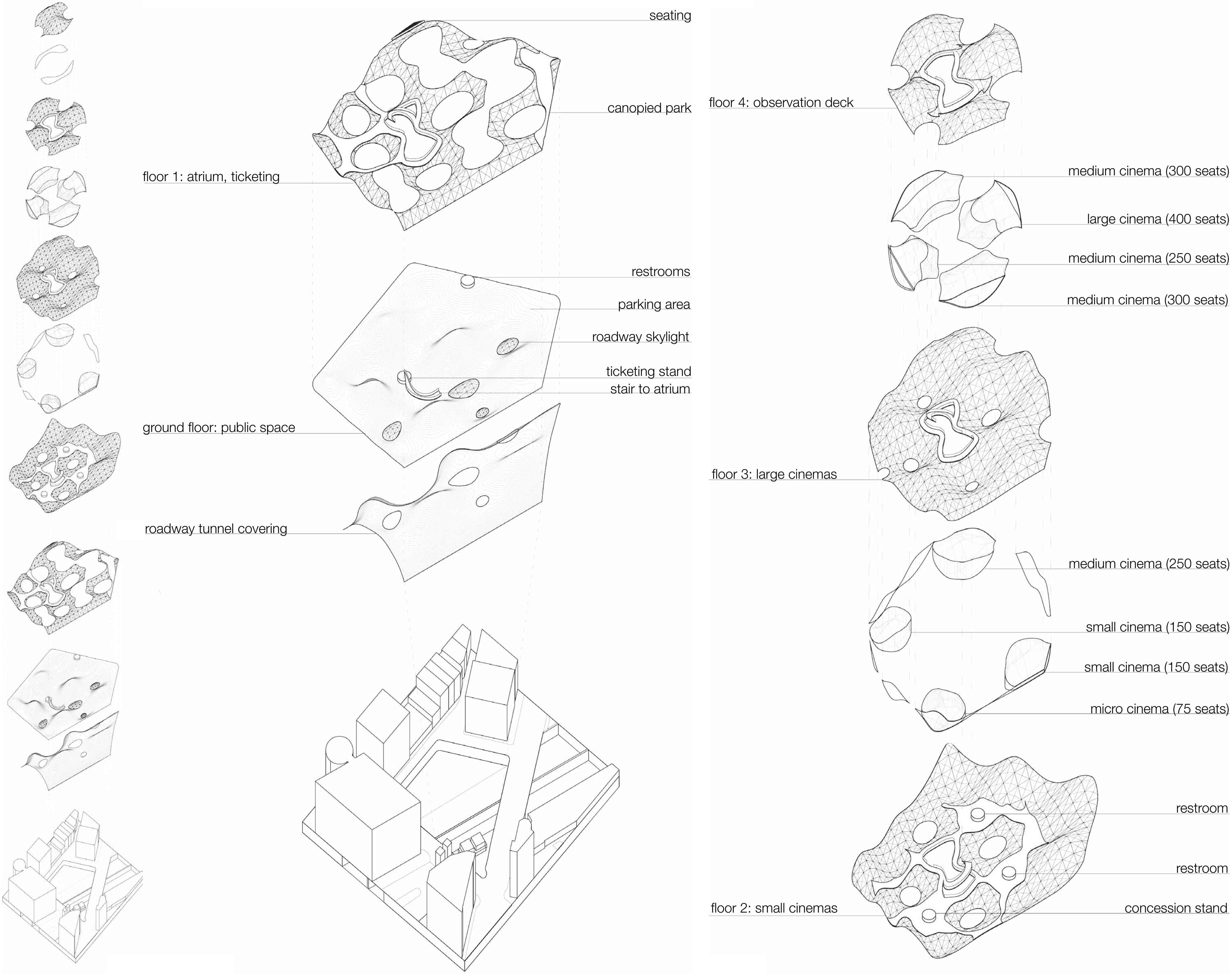


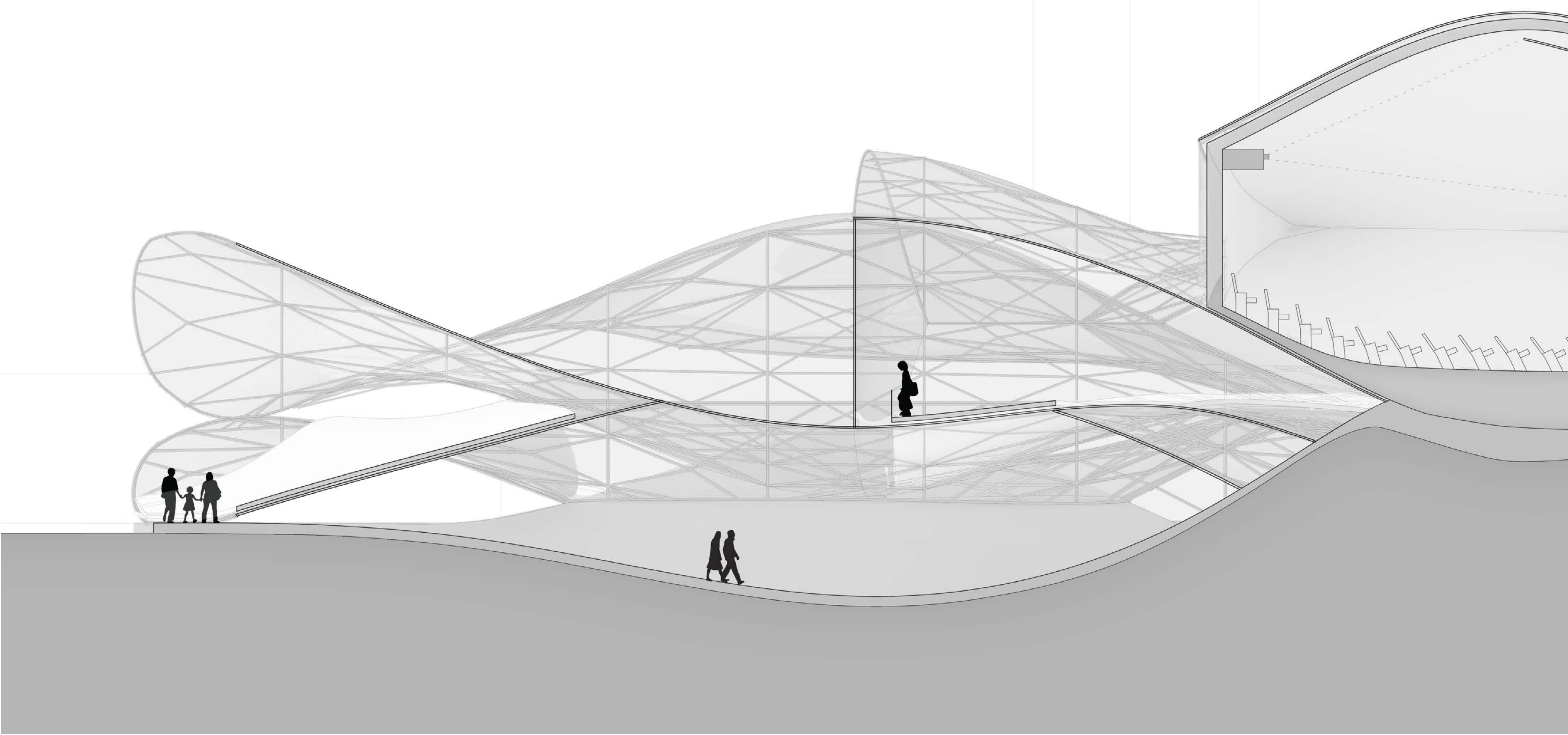
Step 4:
Shift the whole underlying grid of the system to one side to create different sizes of program space.



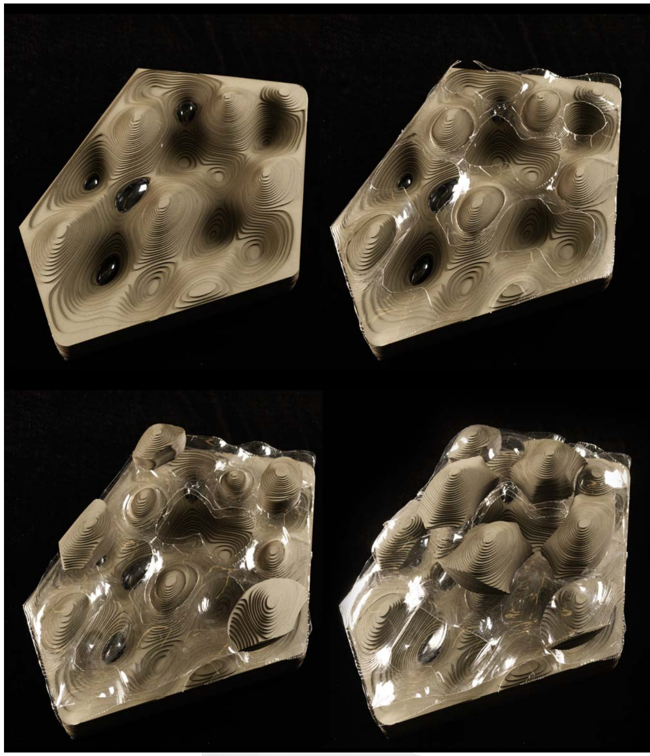


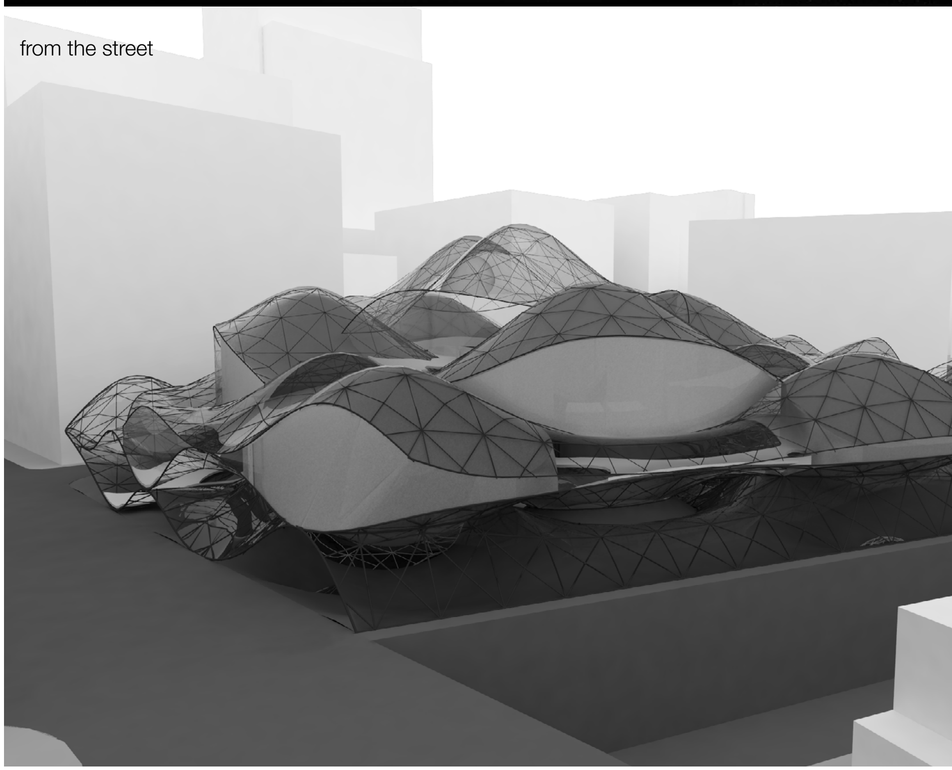
3rd floor plan

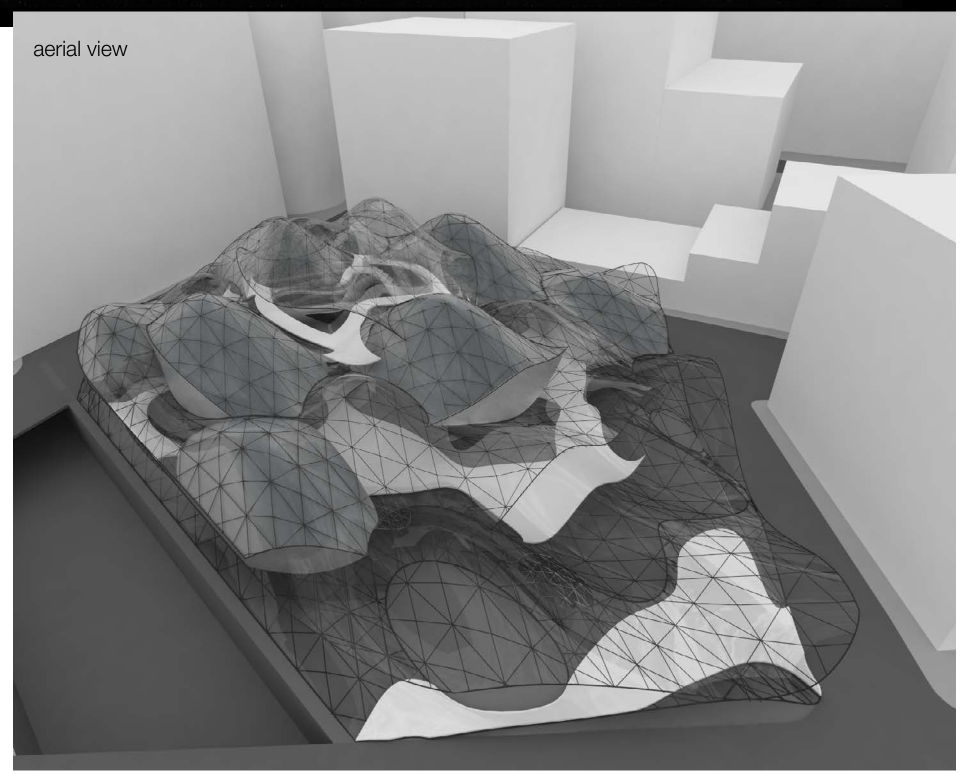

seating
canopied park
floor 1: atrium, ticketing
restrooms
parking area
roadway skylight
ticketing stand
stair to atrium
ground floor: public space
roadway tunnel covering
floor 4: observation deck
medium cinema (300 seats)
large cinema (400 seats)
medium cinema (250 seats)
medium cinema (300 seats)
floor 3: large cinemas
medium cinema (250 seats)
small cinema (150 seats)
small cinema (150 seats)
micro cinema (75 seats)
restroom
restroom
concession stand
floor 2: small cinemas




final model (top view)




from the street


aerial view

solar hearth home

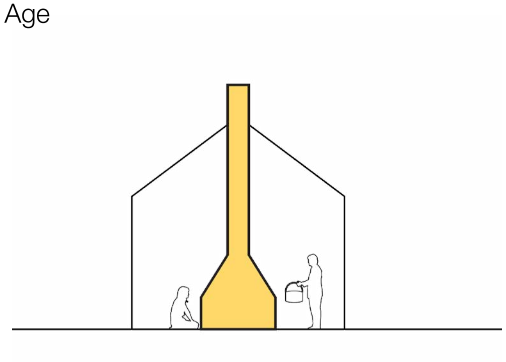
It was not long ago that many architects conceived of the home with its primary energy system - the hearth - at its center. In this traditional view of the hearth as a home's primary energy system, nearly all activity occurred around this central axis and communal feelings were associated with the space around it. Today in the oil age, however, these hearths have become merely decorative as we presently tend to shove our current energy systems into our basements, up to our roofs or disperse them around our homes. As we enter into an age of energy consciousness with the enlightened understanding that there is more than enough solar power falling on a site of a single family home to satisfy its energy needs, there is an opportunity to re-establish this lost home energy center.

The solar hearth home imagines the impact of establishing a solar energy center within the modern home and proposes that such a center could be a topographic thermally active floor slab, which captures and distributes incoming sun energy. Above this, a dome and an oculus were chosen to allow uninterrupted access of the sun to this "hearth." Additionally, the dome and oculus reinforce the notion of center within the home and capitalize on a compressive form with a high thermal mass and low surface area to volume ratio that is well-suited to the temperate climate.

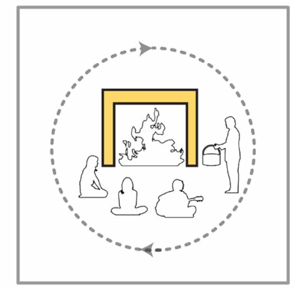
Project Type - Academic
Role - Designer (the only one)
Duration - 13 Weeks
Date - Fall 2012
Location - Hingham, MA

Macro Concept - The Solar Hearth

Wood Age

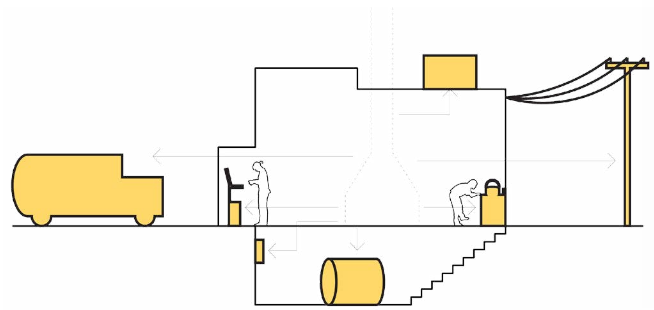


Unified Home Center

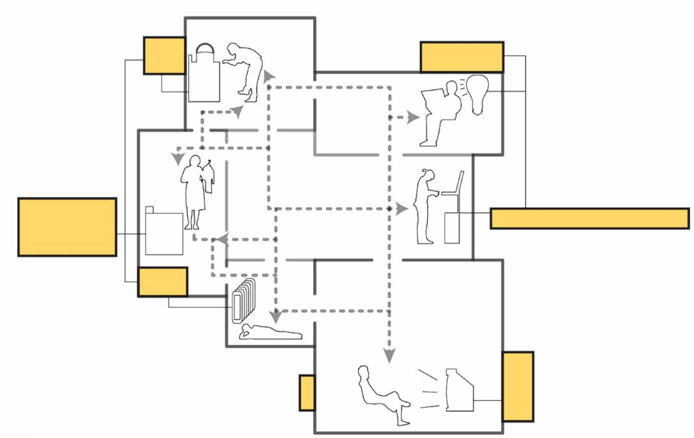


Interaction Occurs Around Center

Oil Age

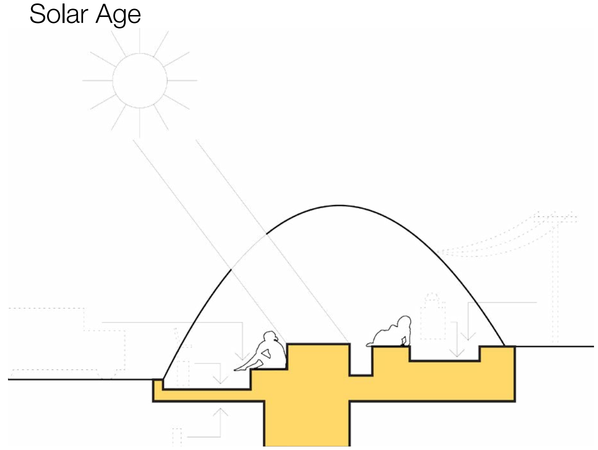


Fractured Home Center

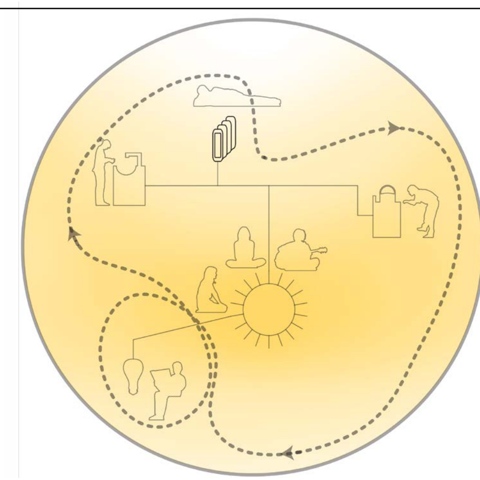


Interaction Occurs Between Components

Solar Age



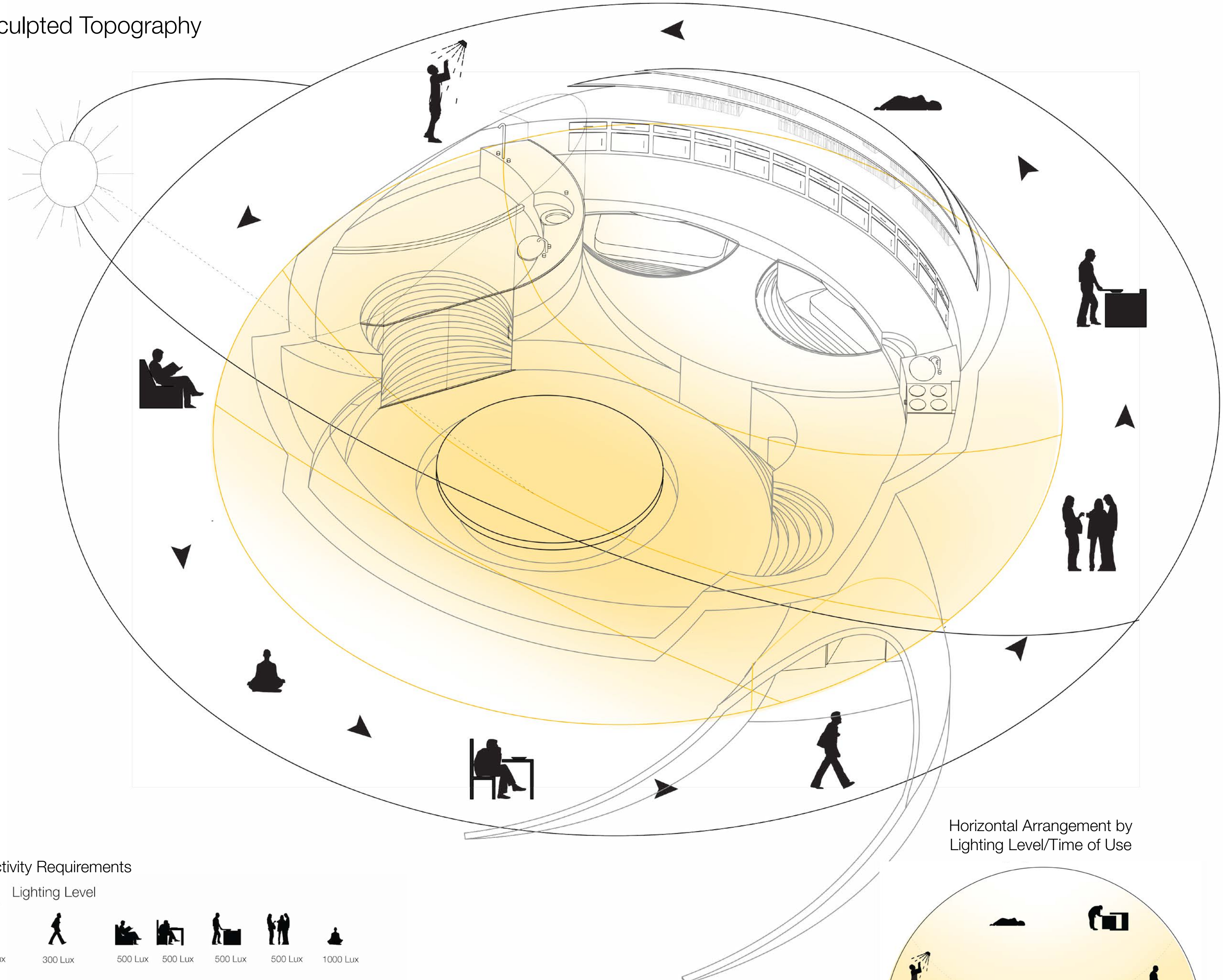
Re-Unified Home Center



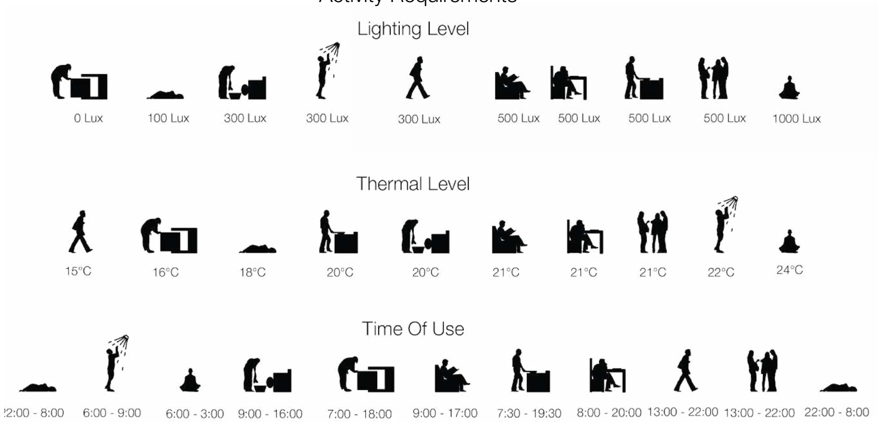
Interaction Occurs Throughout Center

Micro Concept - Sun-Sculpted Topography

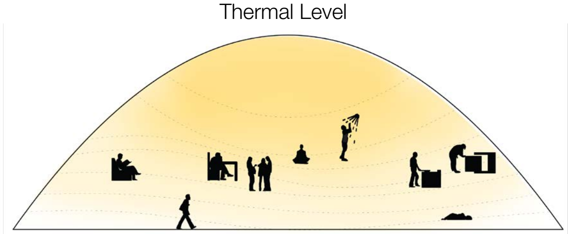
Activities



Activity Requirements



Vertical Arrangement by Thermal Level

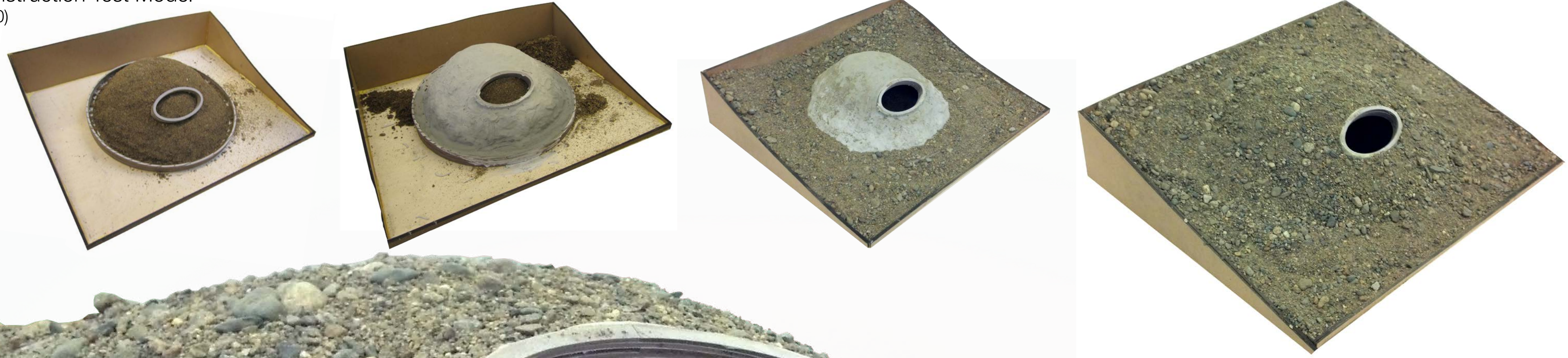


Horizontal Arrangement by Lighting Level/Time of Use

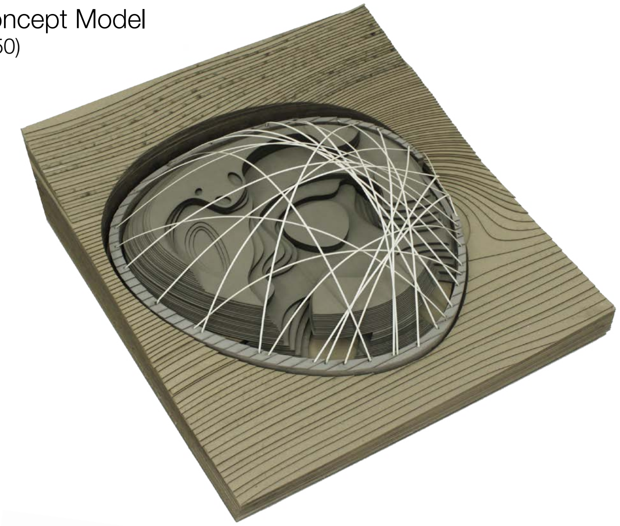
Structural Test Models

Interior Finish Test Models

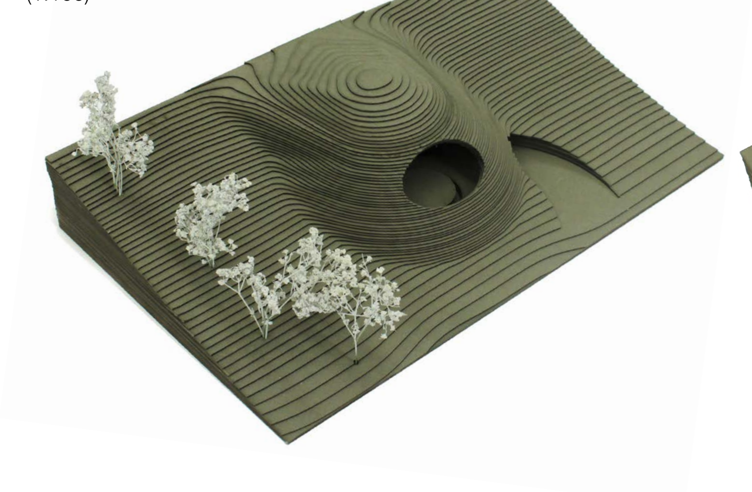
Construction Test Model
(1:50)



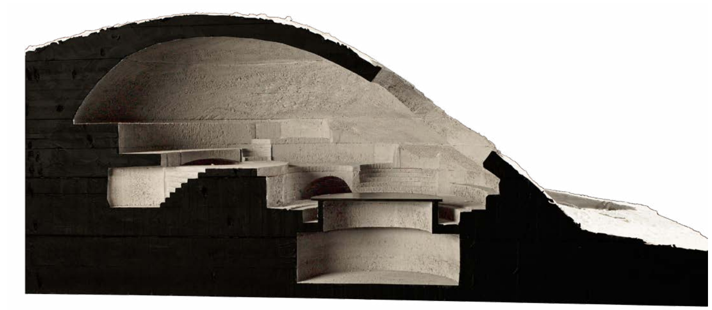
Concept Model
(1:50)



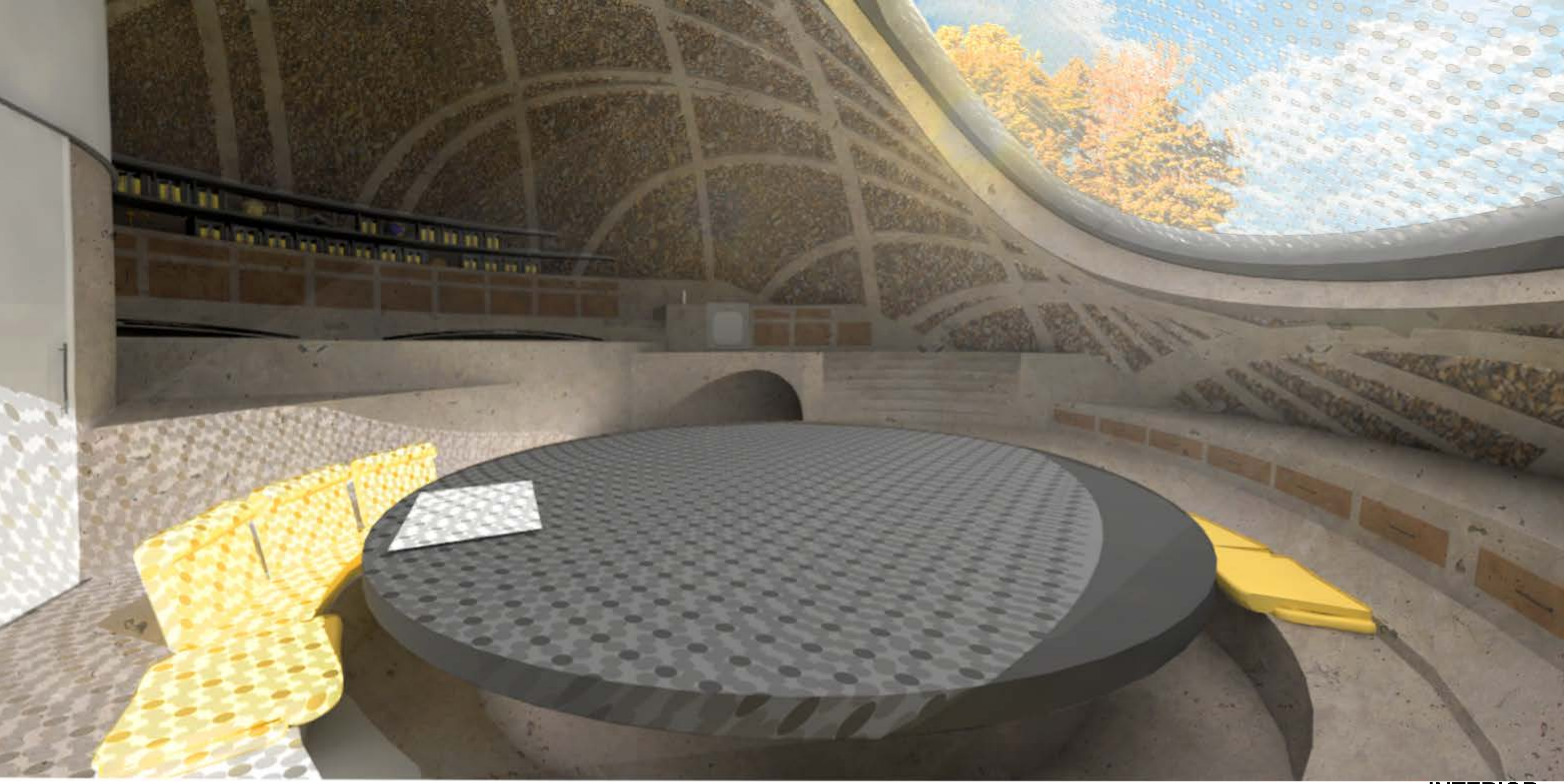
Site Model
(1:100)



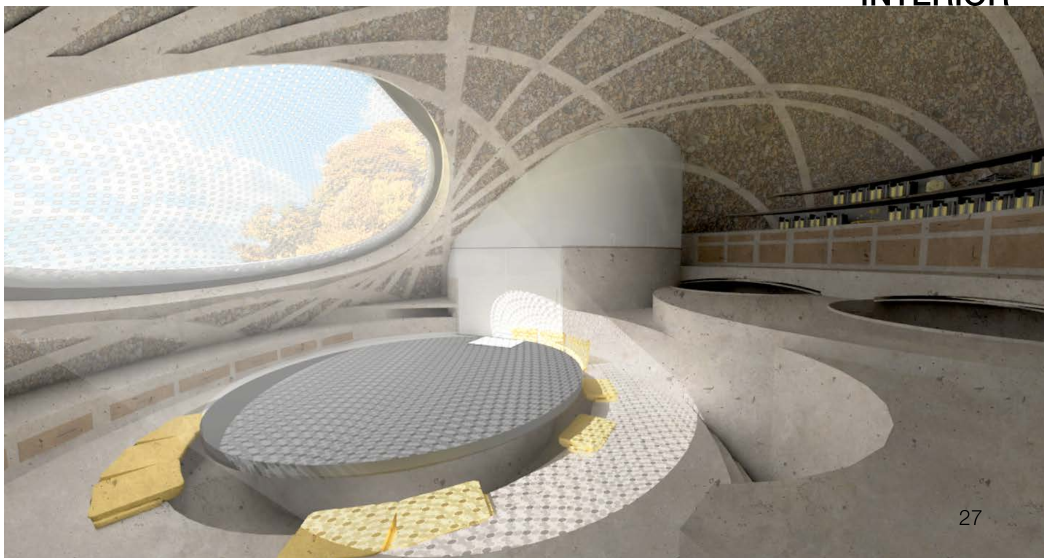
Detail Model
(1:20)



EXTERIOR



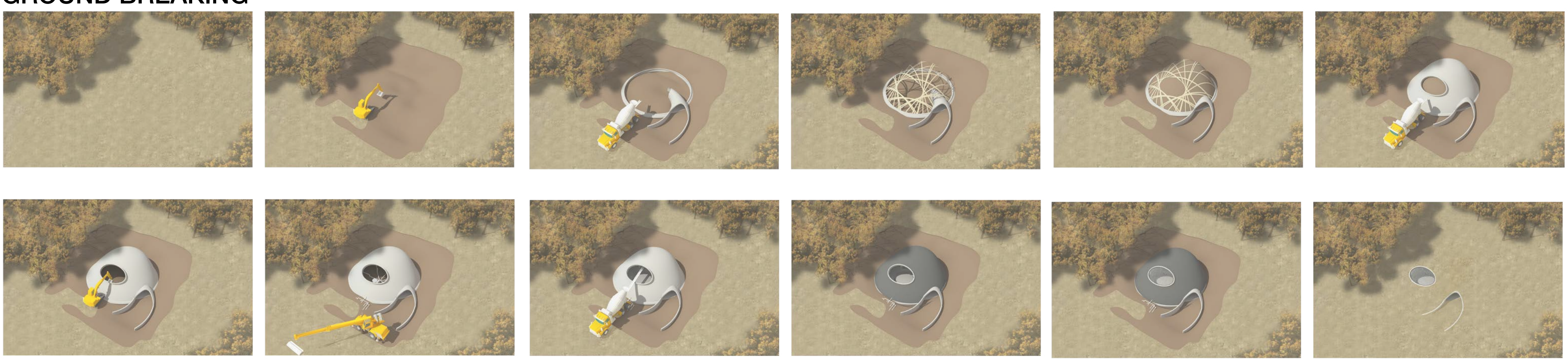
INTERIOR



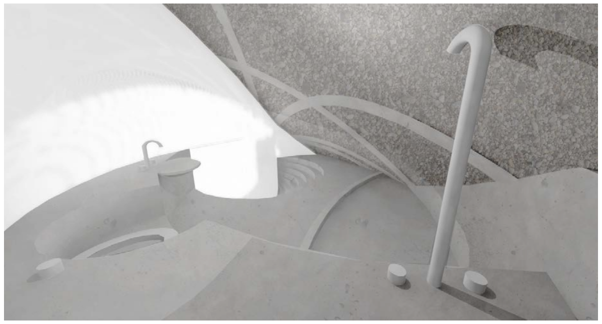
MORNING

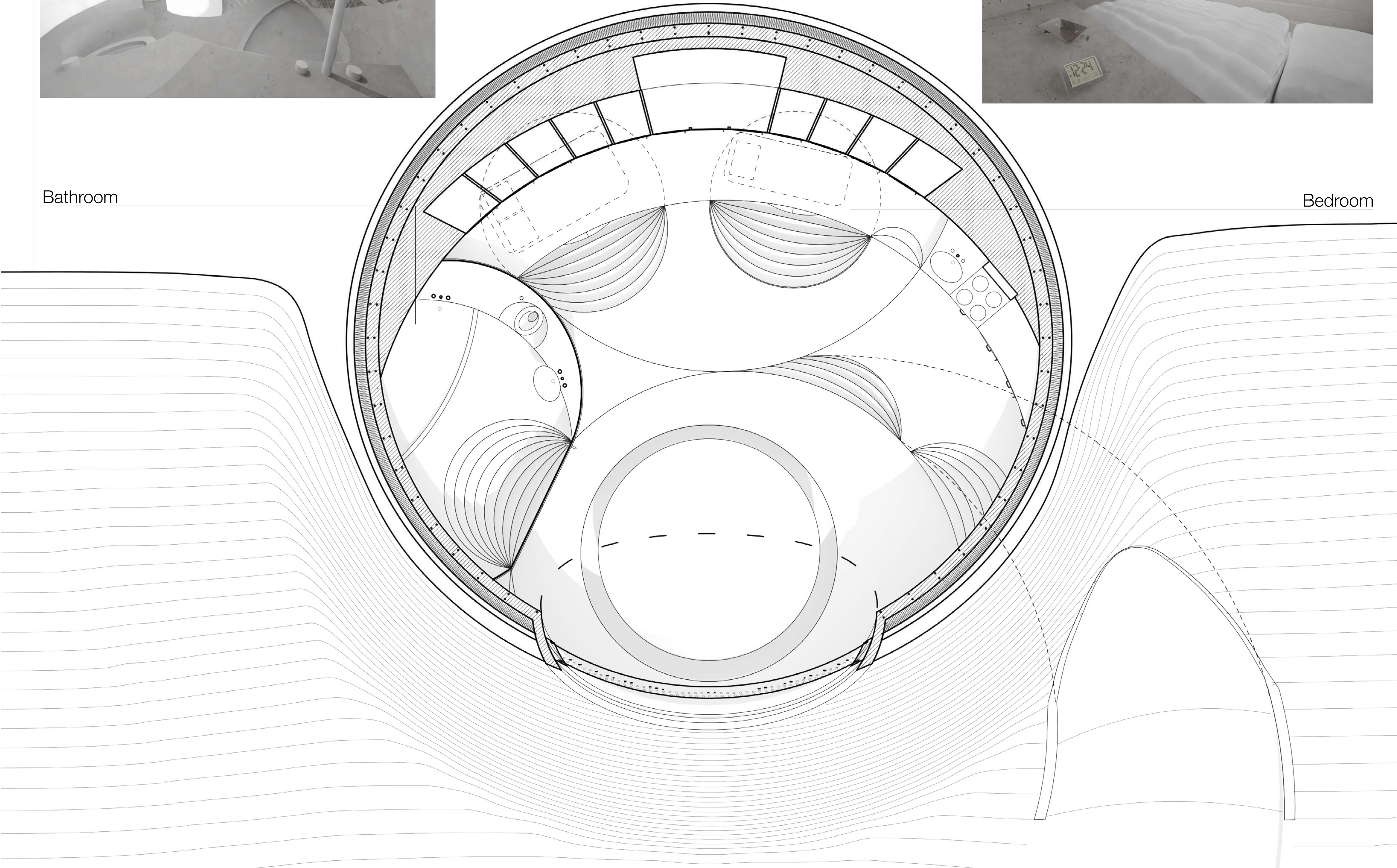
EVENING

GROUND BREAKING

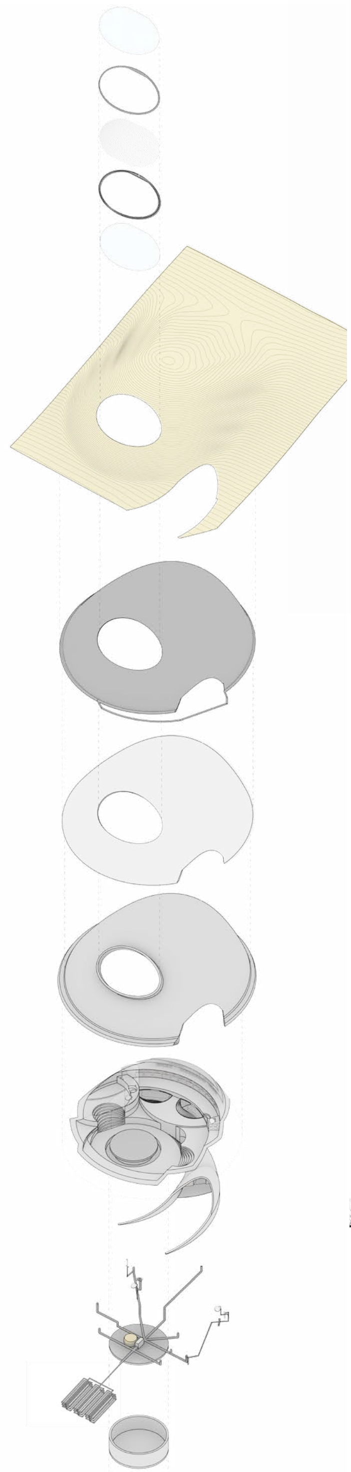


COMPLETION

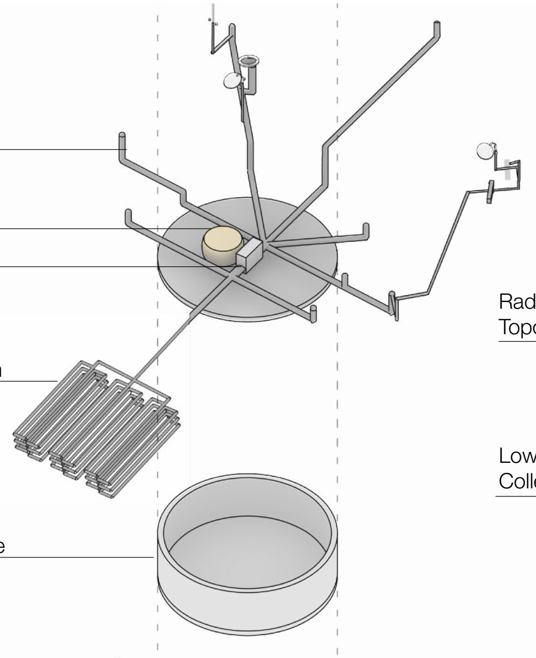


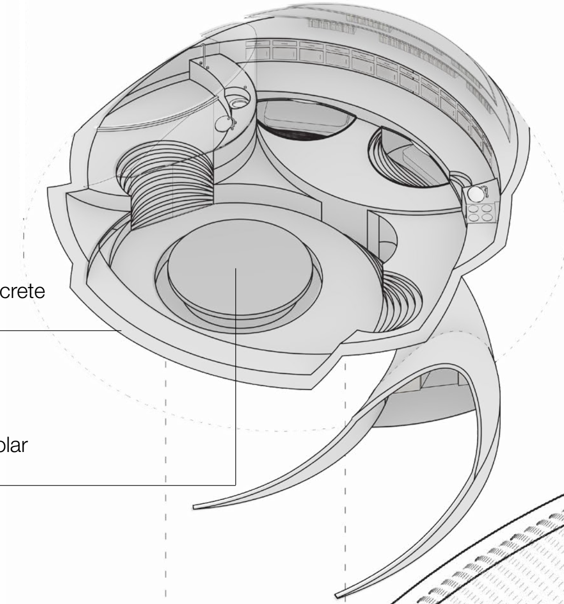

Bathroom
Bedroom

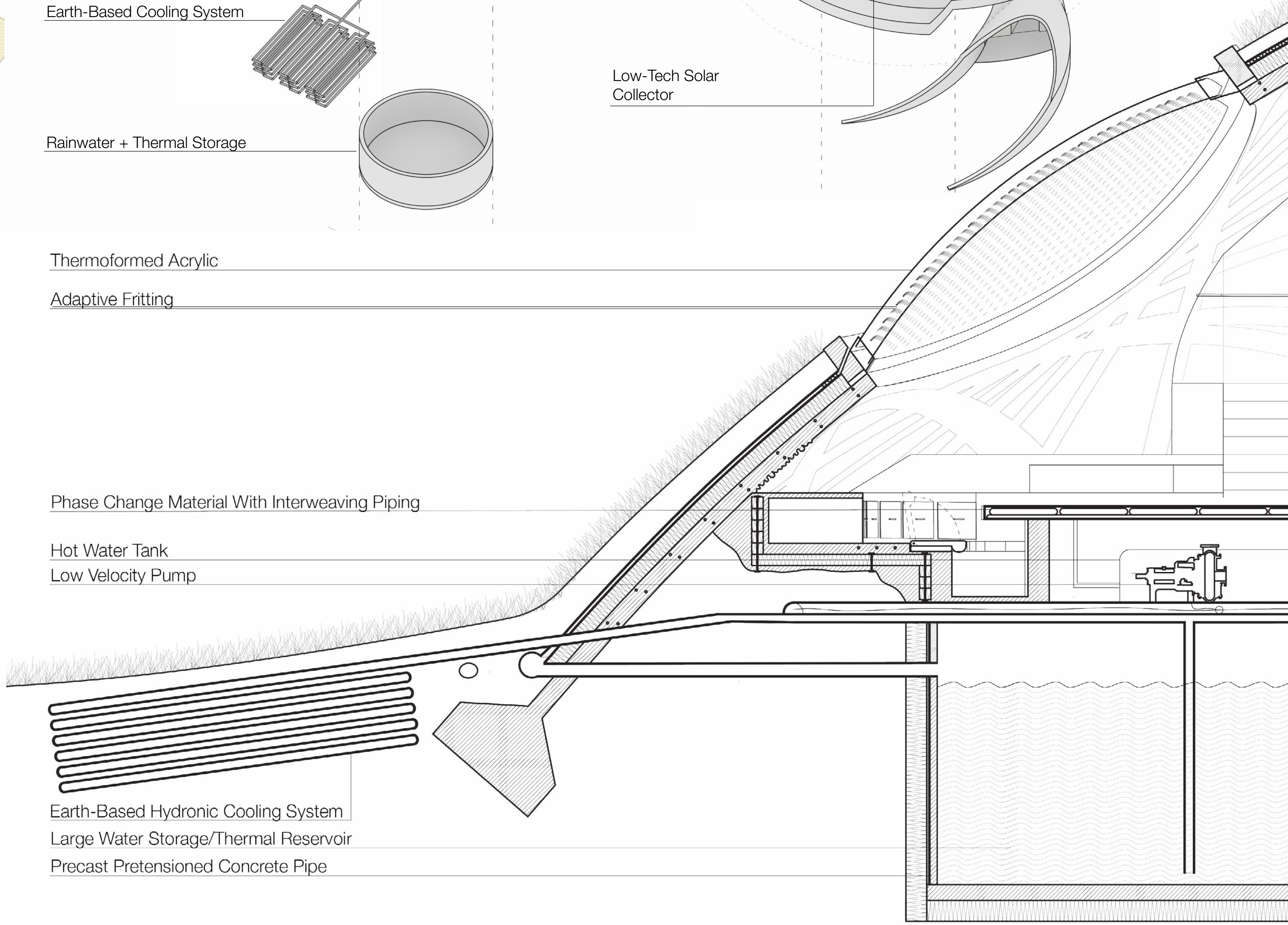
Full Axon

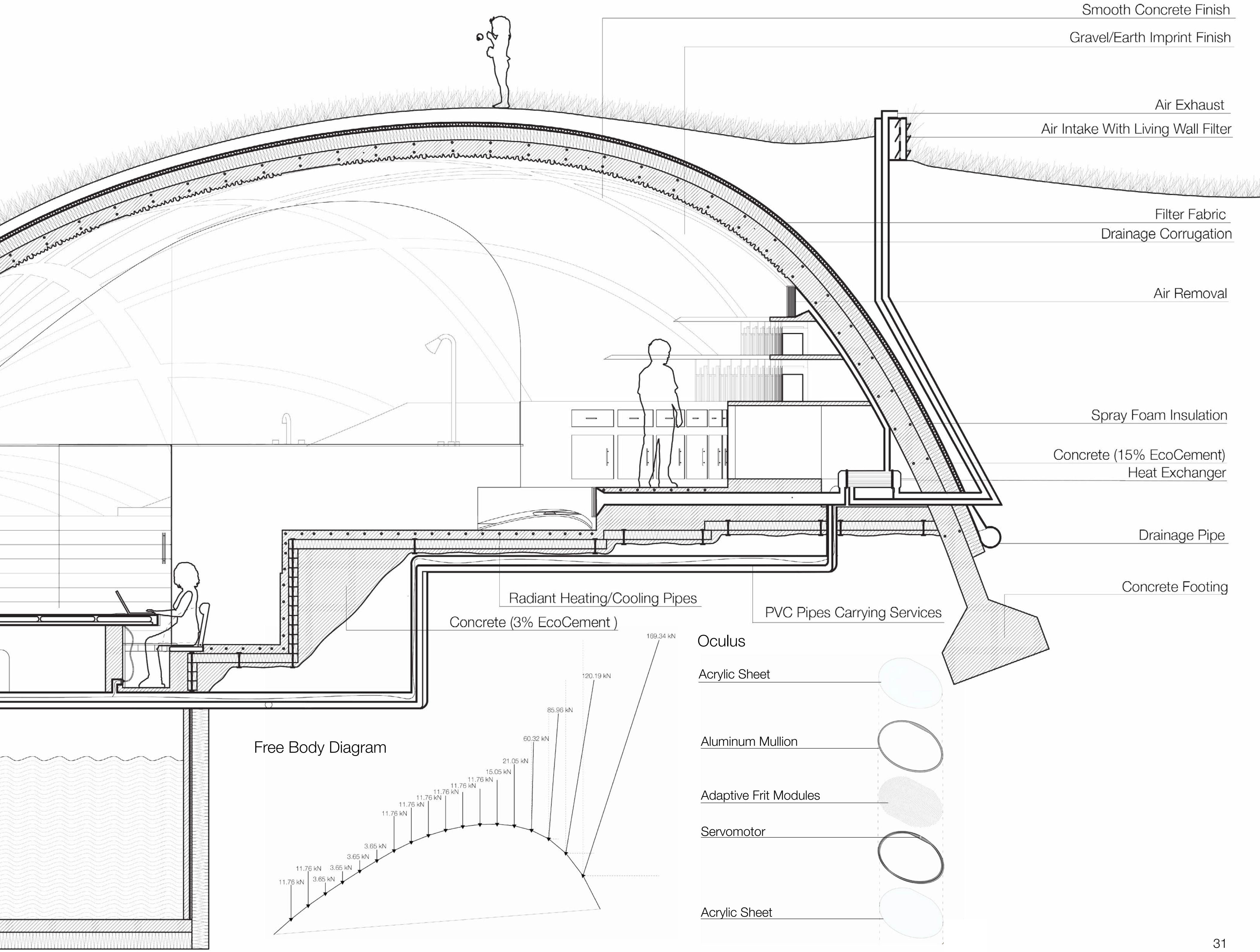


Solar Hearth









Smooth Concrete Finish
Gravel/Earth Imprint Finish
Air Exhaust
Air Intake With Living Wall Filter
Filter Fabric
Drainage Corrugation
Air Removal
Spray Foam Insulation
Concrete (15% EcoCement)
Heat Exchanger
Drainage Pipe
Concrete Footing
Radiant Heating/Cooling Pipes
PVC Pipes Carrying Services
Concrete (3% EcoCement)
Oculus
Acrylic Sheet
Aluminum Mullion
Adaptive Frit Modules
Servomotor
Acrylic Sheet
Free Body Diagram
169.34 kN
120.19 kN
85.96 kN
60.32 kN
21.05 kN
15.05 kN
11.76 kN
11.76 kN
11.76 kN
11.76 kN
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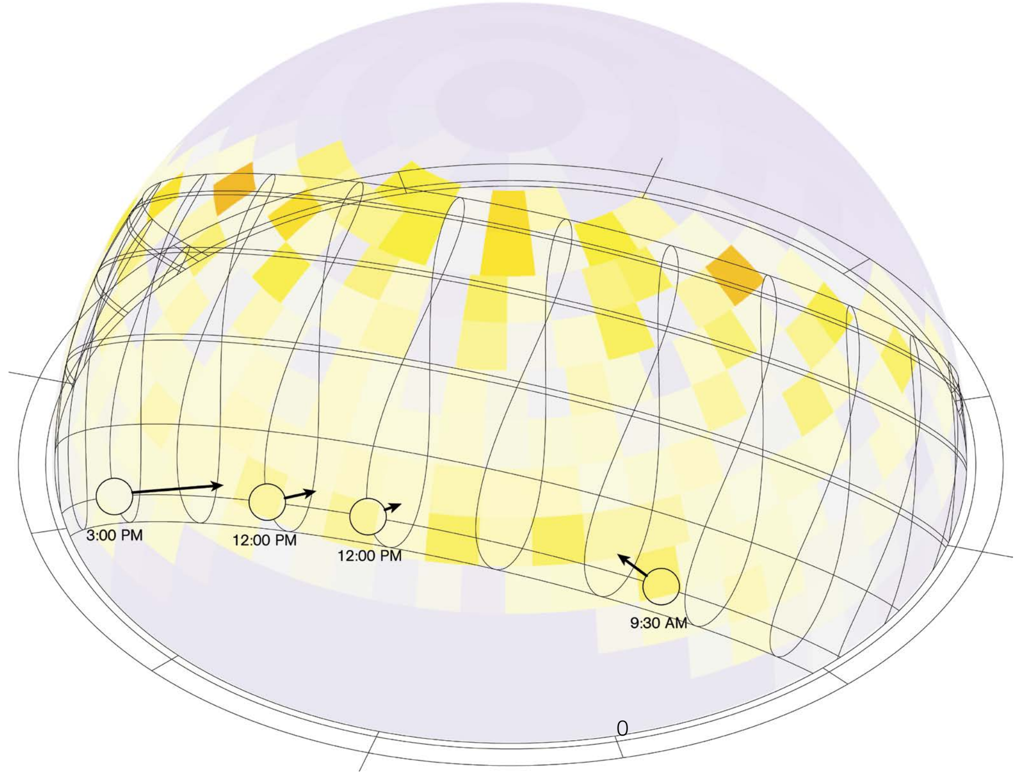
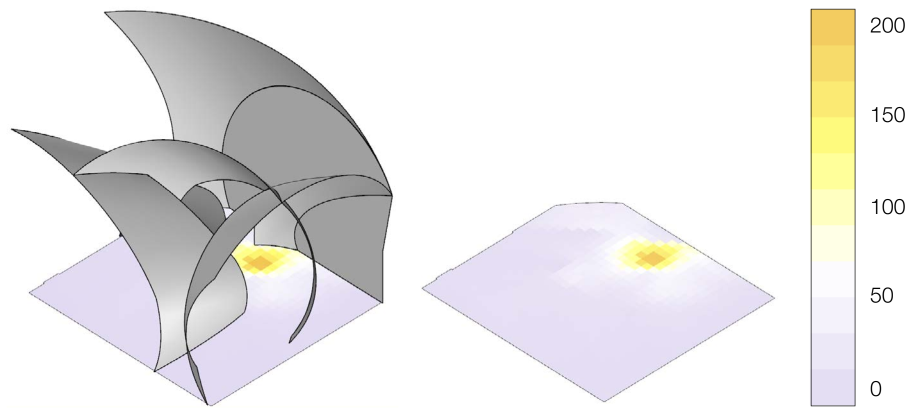
11.76 kN

sun sculpted artspace

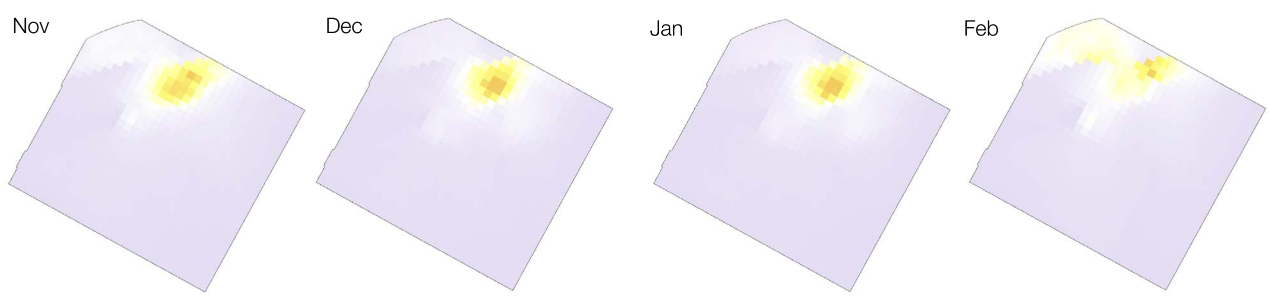
The sun sculpted artspace takes as its driving parti a set of four intersecting parabolic objects that select for certain desired conditions within the art galleries and performance spaces. Specifically, the parabolic objects order and focus rays of sunlight at key hours of the year, helping create the desired conditions of heating the building in the winter and lighting the central gallery space with quality daylight from above.

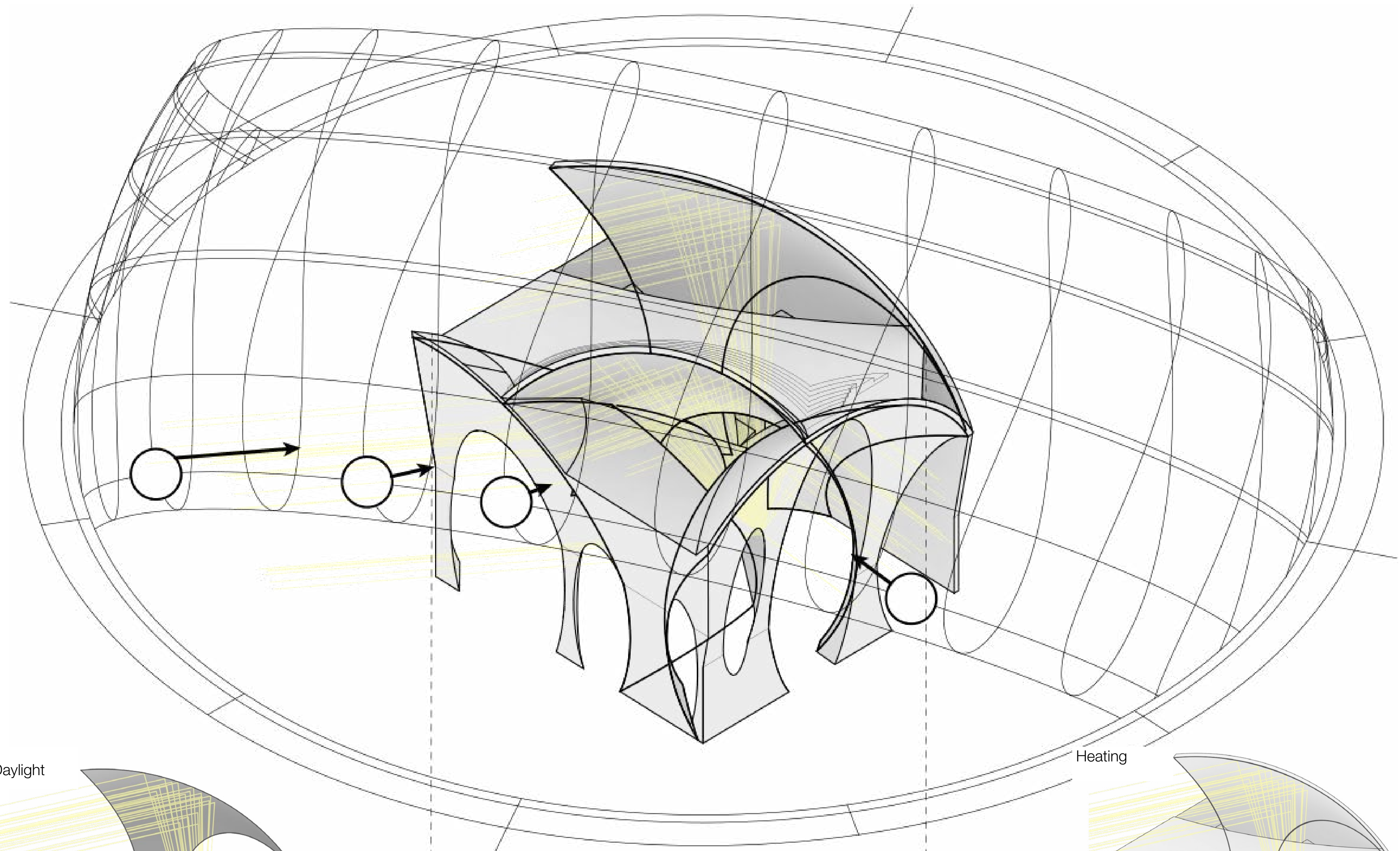
In the final design, each of the four objects is tuned to focus the sun rays at key hours of the winter when outdoor conditions are cold but solar radiation is at some of the highest levels all year: 10:30 AM, 11:30 AM, 12:30 PM, and 1:30 PM. In addition to heating benefits received this way, these bespoke objects also provide a desired condition of daylight throughout the year by reflecting the bright outdoor light downward towards the gallery but diffusing it enough to not cause glare for the art viewers. The parabolic nature of these objects is also exploited in the case of the music/performance space to create desired acoustic conditions that reflect sound waves outward and away from the audience instead of echoing back in their ears.



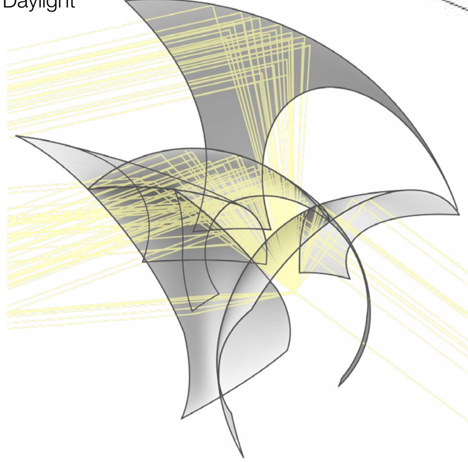


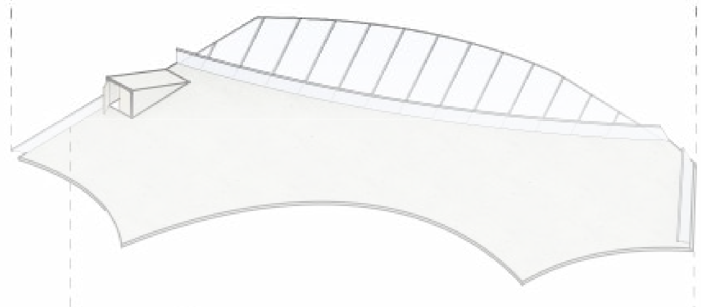
Project Type - Academic
Role - Designer (the only one)
Duration - 13 Weeks
Date - Spring 2014
Location - Manhattan, NY



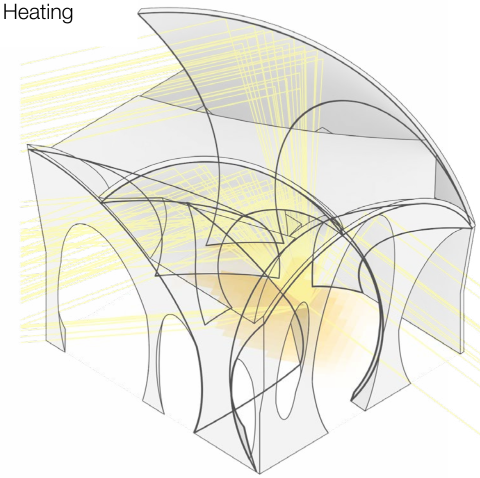


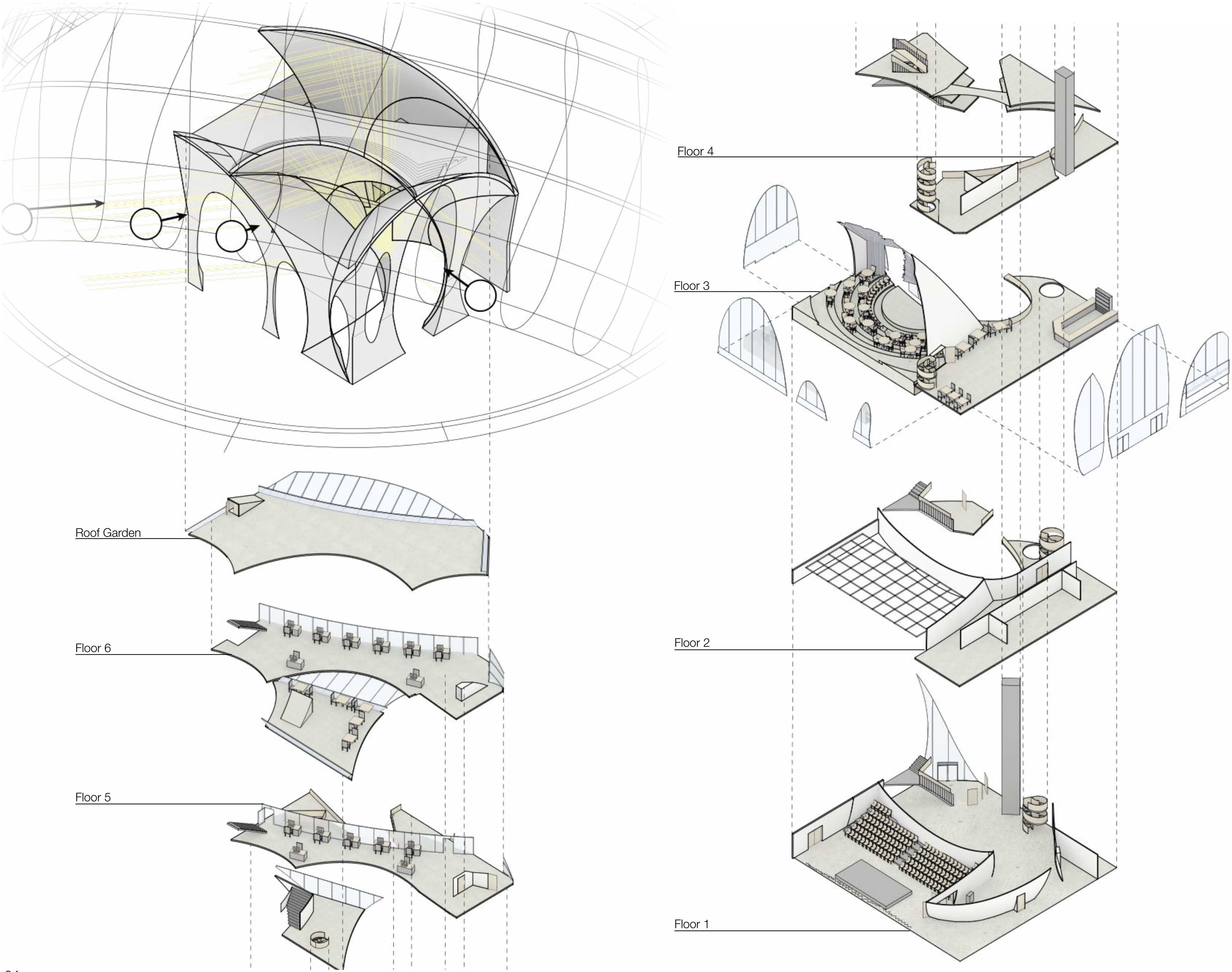
Daylight

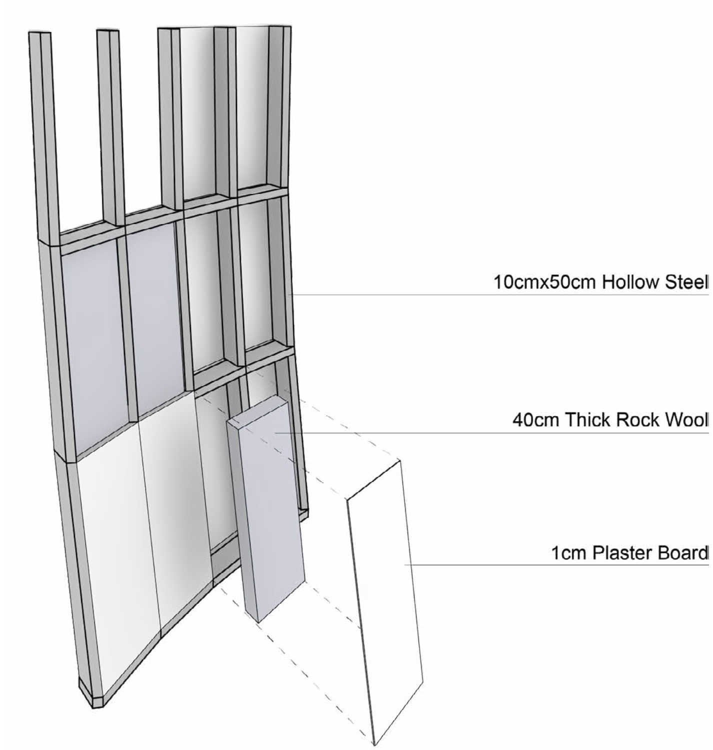


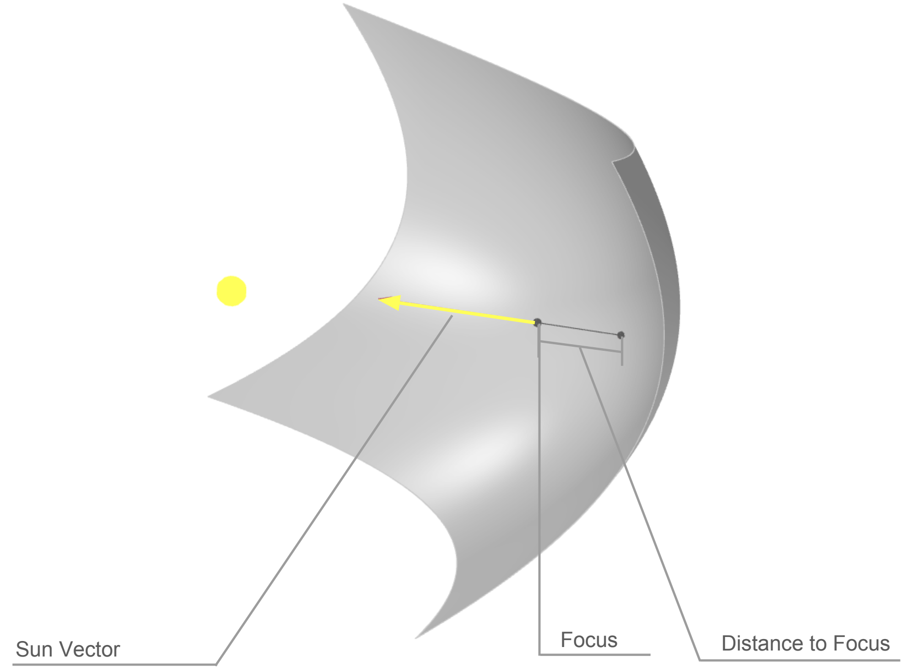


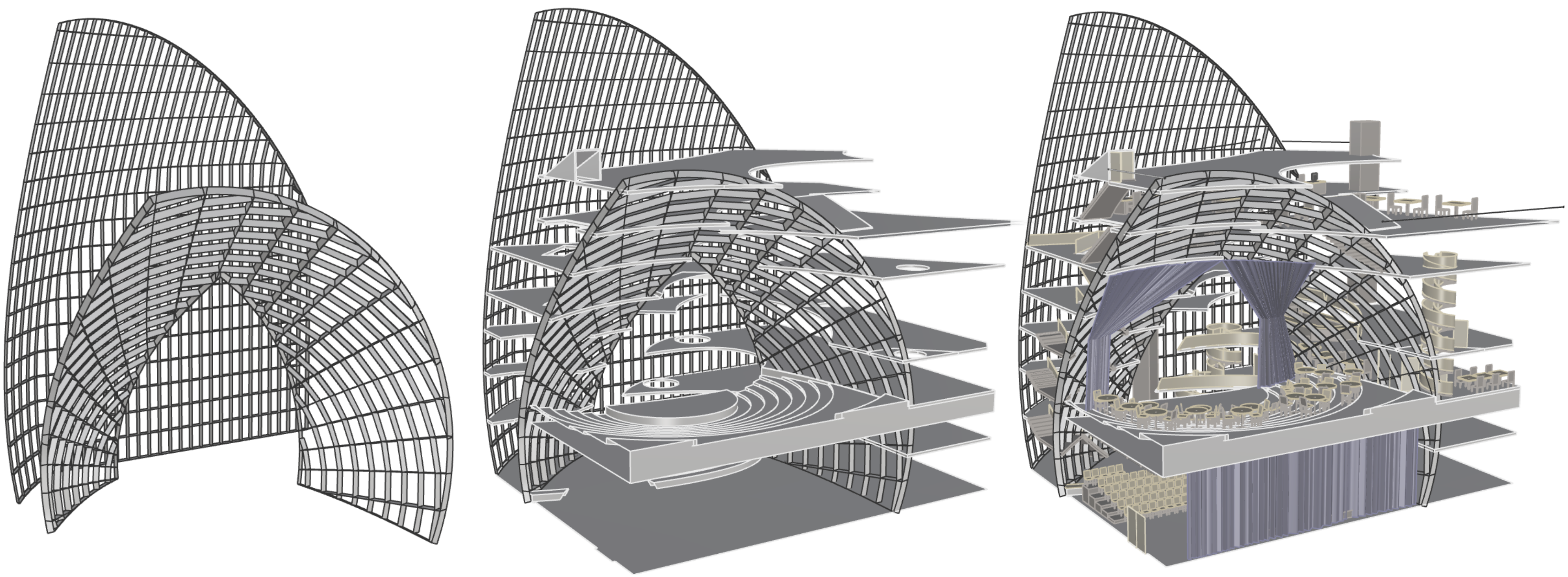
Heating




Floor 4
Floor 3
Roof Garden
Floor 2
Floor 6
Floor 5
Floor 1


10cmx50cm Hollow Steel
40cm Thick Rock Wool
1cm Plaster Board

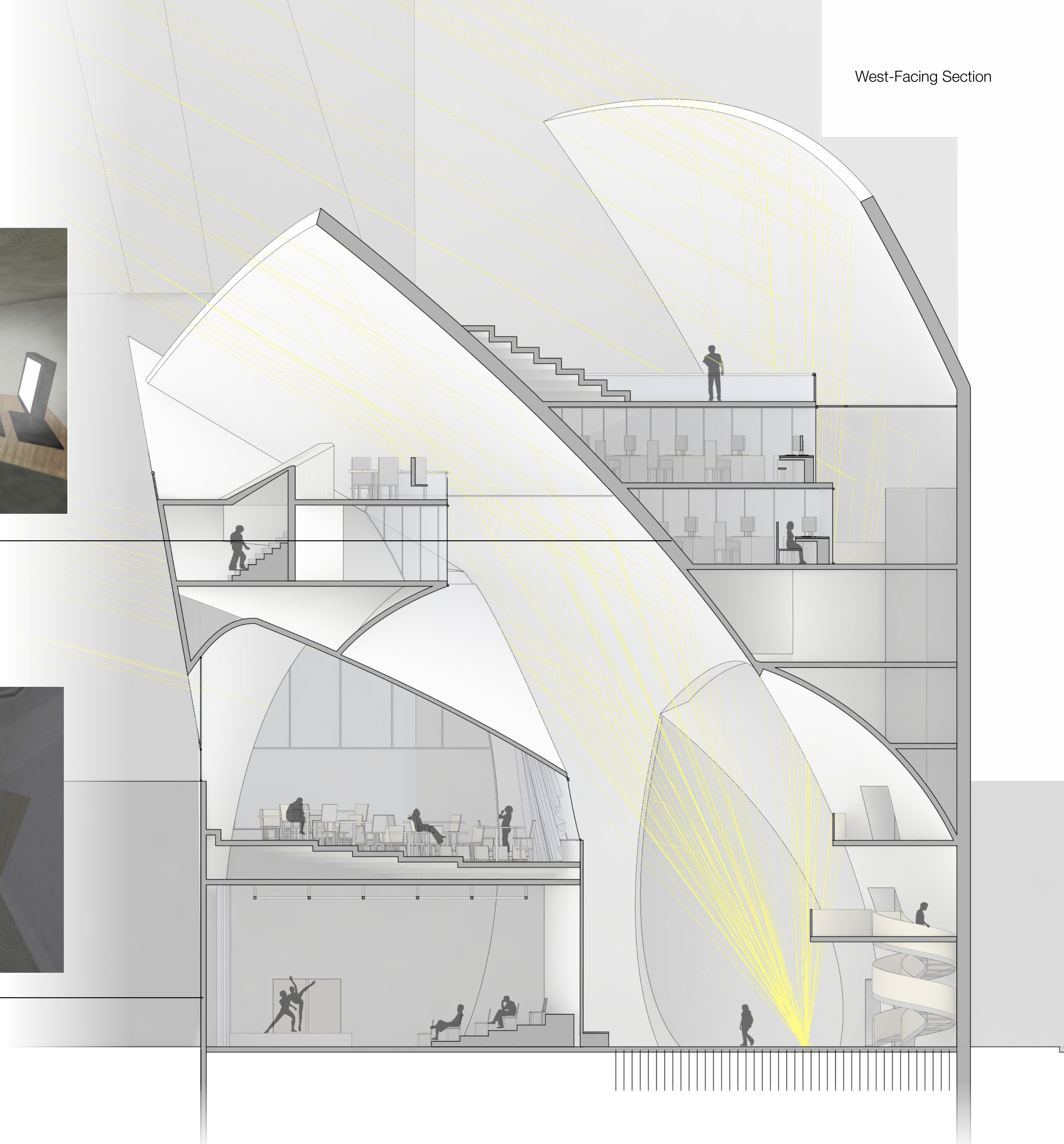

Sun Vector
Focus
Distance to Focus



The areas where the parabolic forms become attenuated and vertical are ideal for housing vertical circulation and for structuring the building.

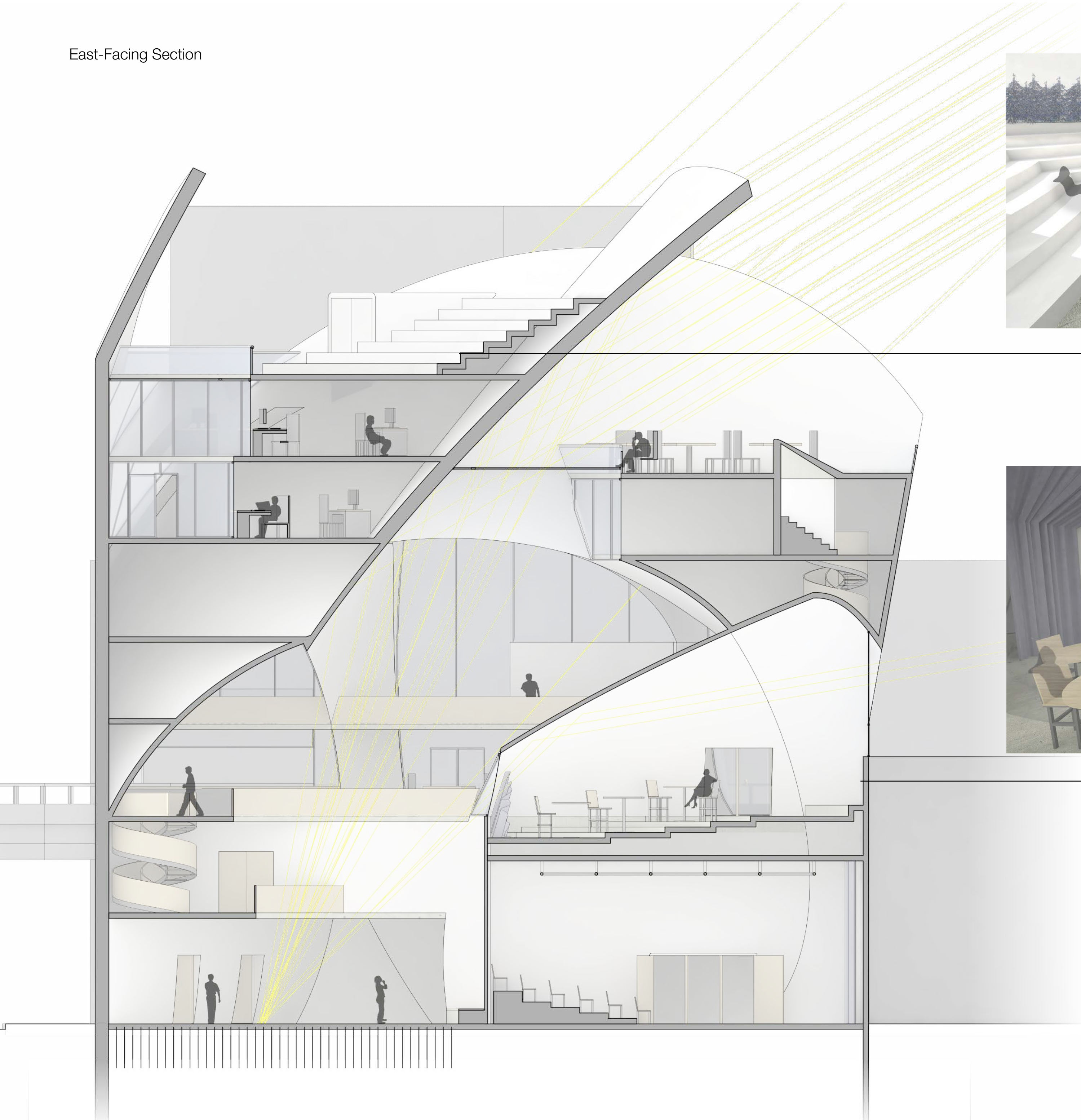
Administrative Offices

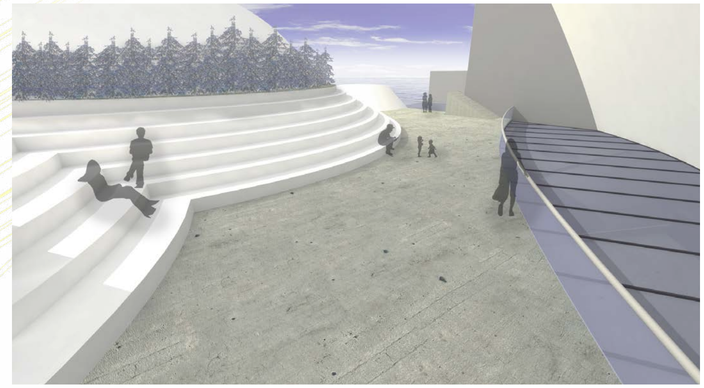
Black Box Theater



West-Facing Section

East-Facing Section



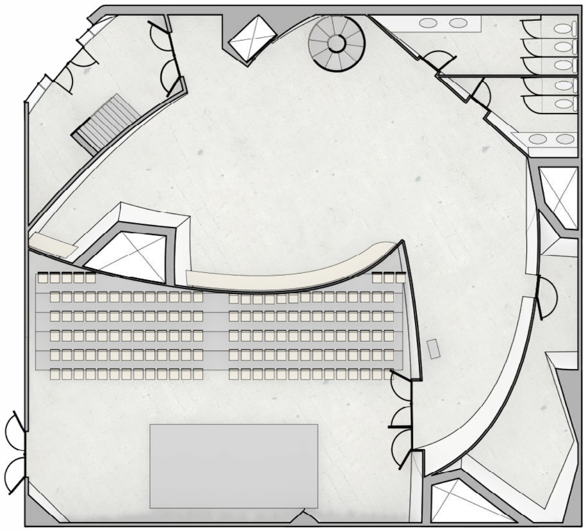


Roof Garden

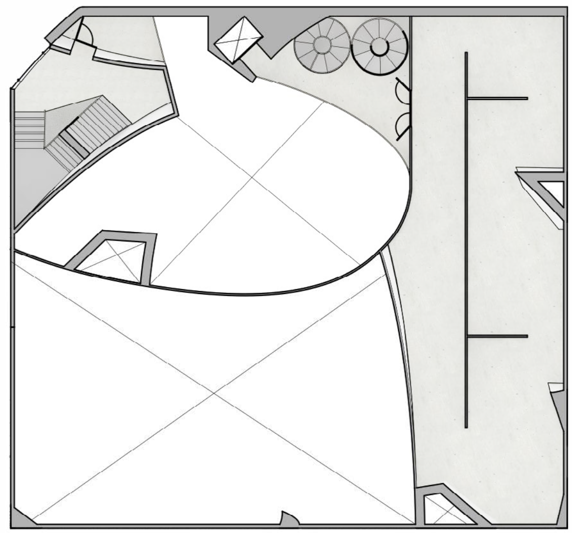
Music Performance Space

In an ideal construction scenario, the arch-like catenary nature of these parabolic forms would also be used to structure the building to be mostly in compression. Thus, minimizing or eliminating the need for conventional steel and using only composite materials.

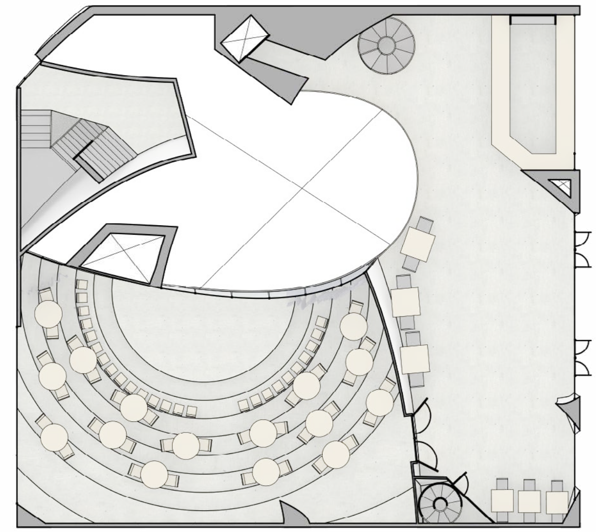
Floor 1



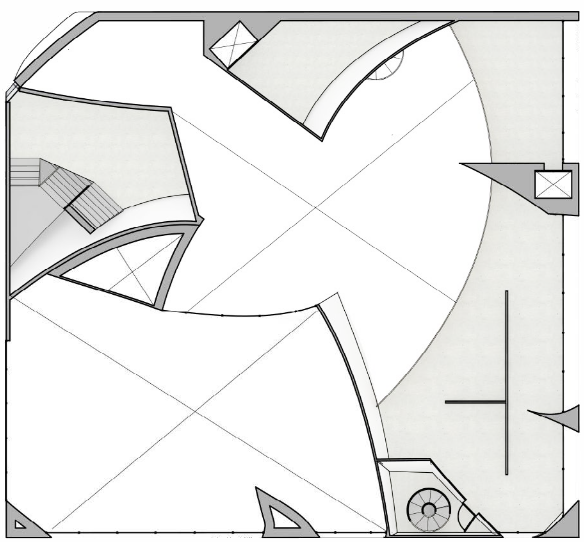
Floor 2



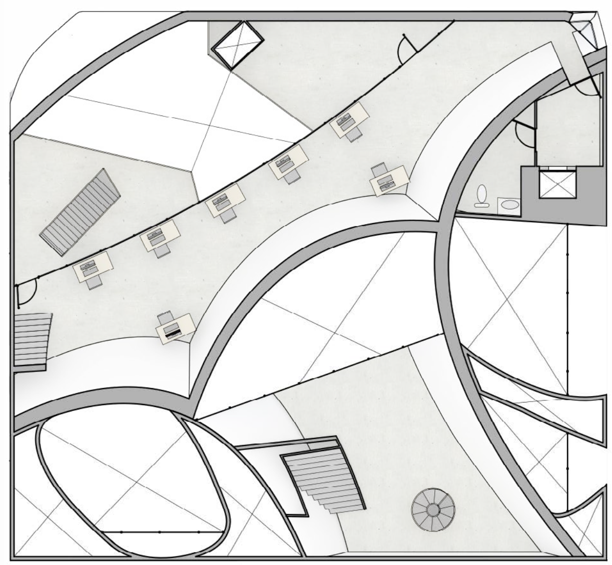
Floor 3



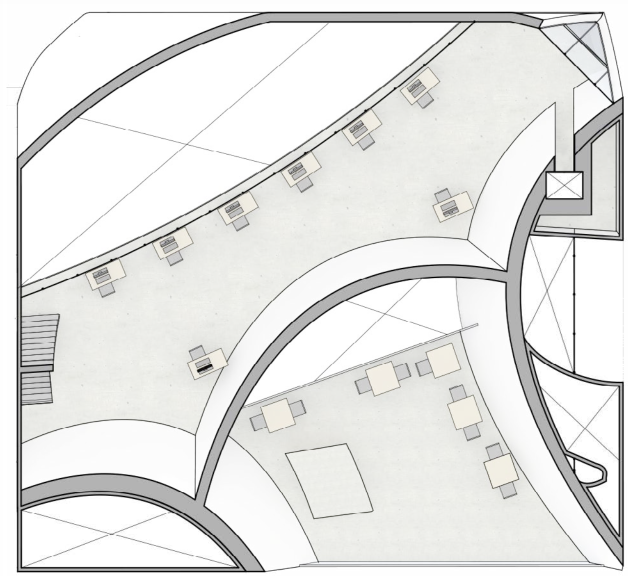
Floor 4



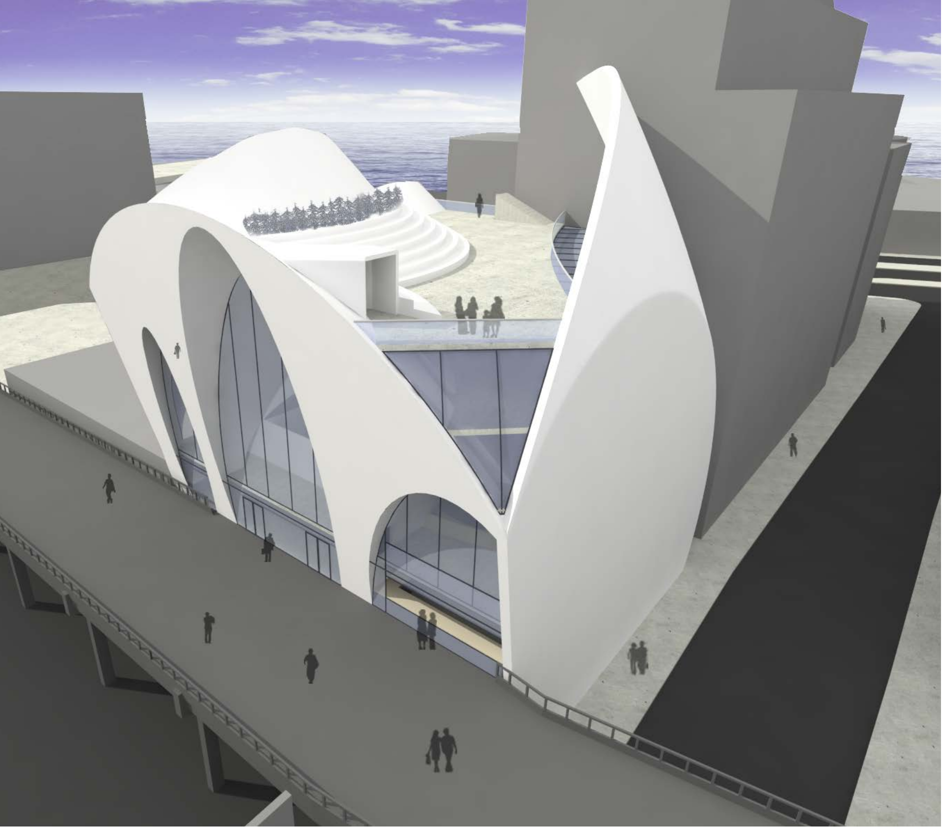
Floor 5

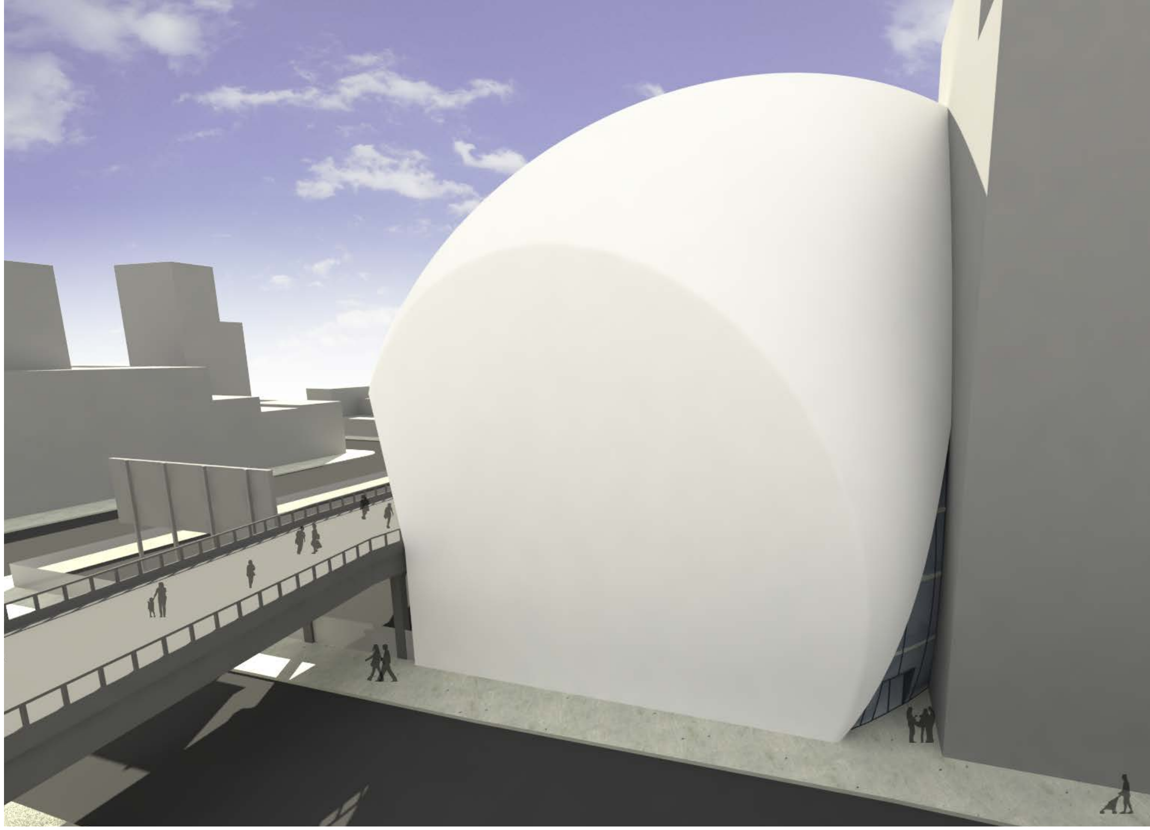


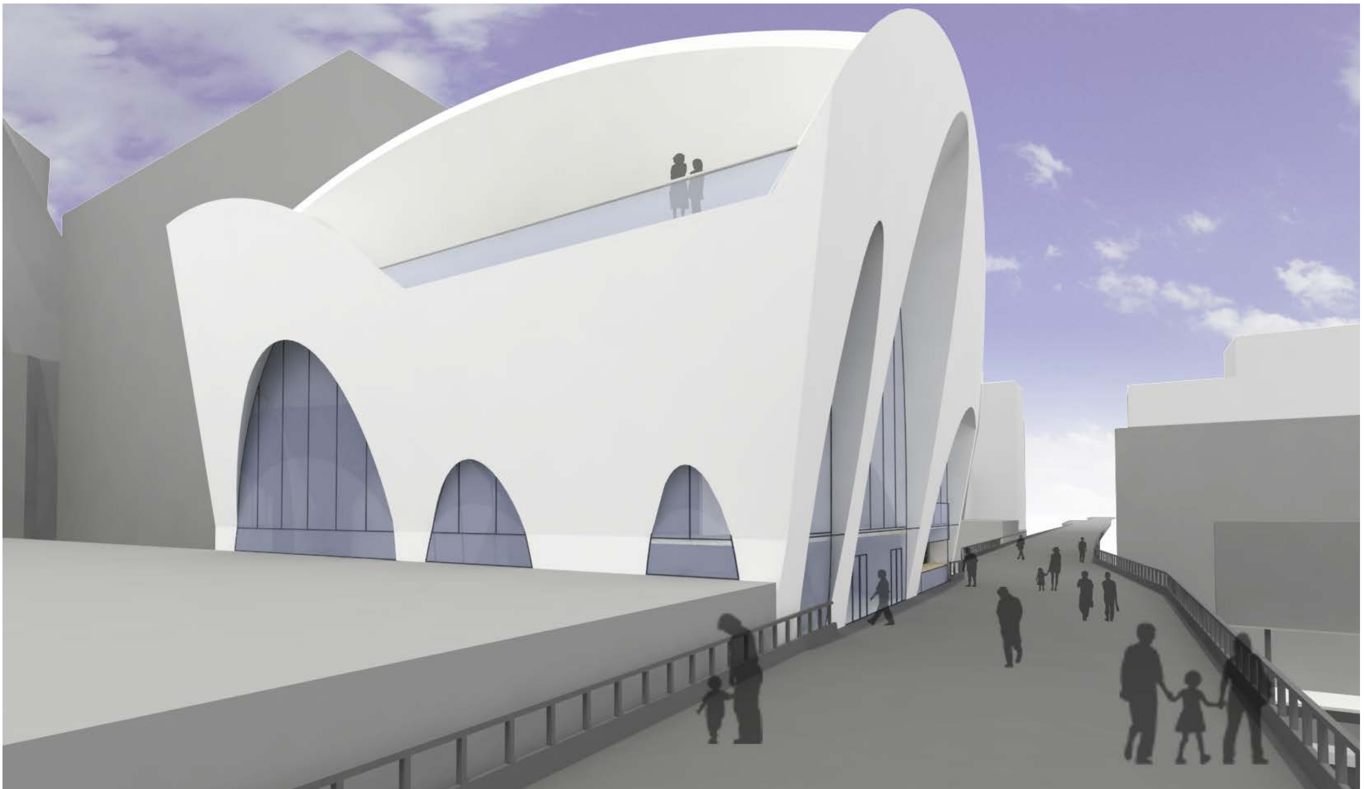
Floor 6



The plans reveal the programmatic strategy of the final design. The first three floors contain most of the public programs while the upper floors are more private and geared towards the artists and administration. The first floor includes a black box theater along with a central daylit gallery meant for the viewing of traditional static art such as painting and sculpture. The second floor is mostly for vertical circulation but possesses a white box enclosed space that can be used for experimental art such as laser light shows. The third floor connects to the NYC highline and possesses a cafe at this connection point in order to lure visitors inside. Adjacent to the cafe is a music space where visitors might hear concerts after purchasing food or beverages at the cafe. The fourth floor includes a workroom for artists as well as a historic gallery documenting past static art exhibits. The top two floors are mostly office space but also include a historic gallery for past performances and overflow roof space for the cafe.







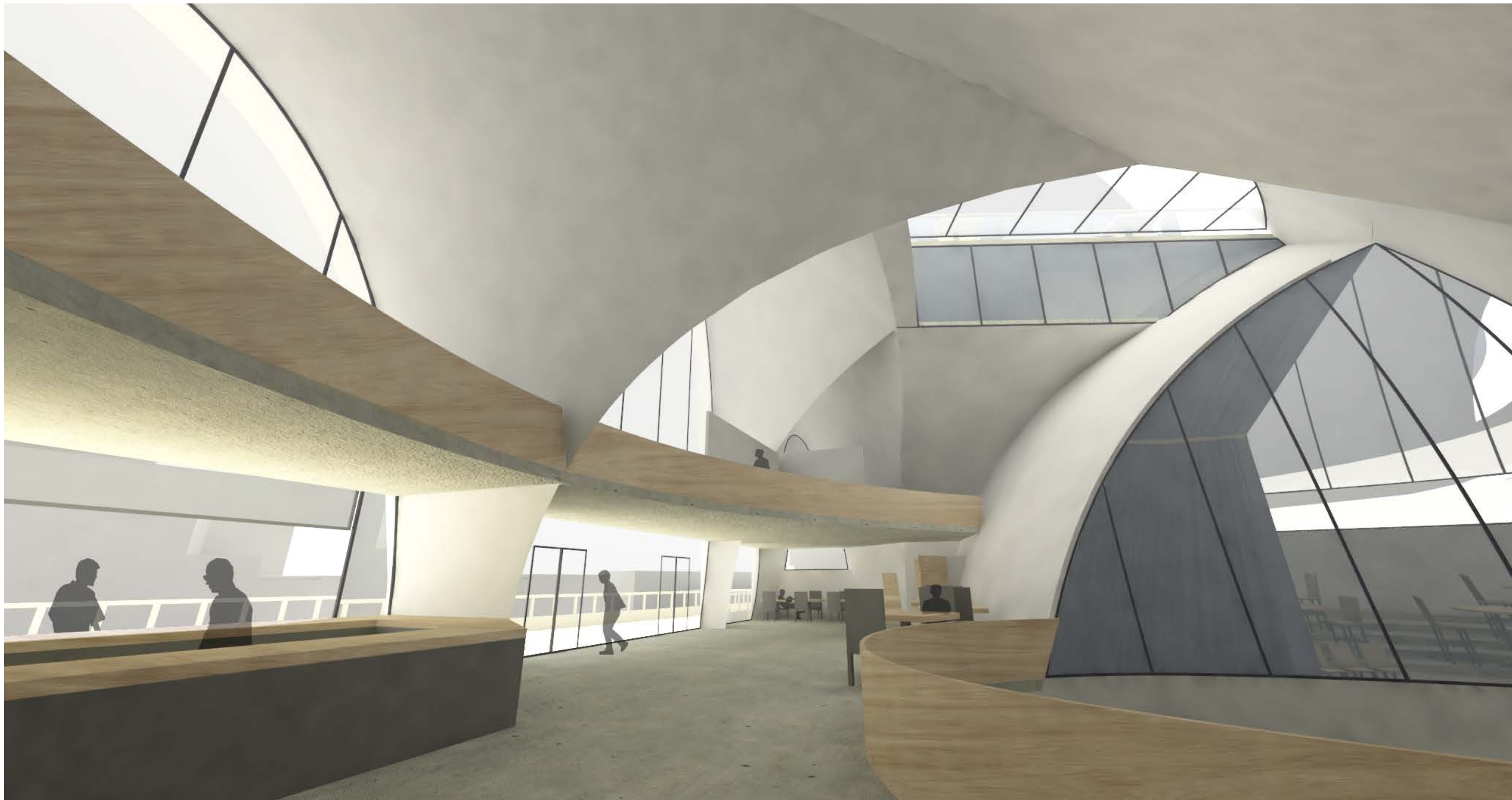
The exterior facade is treated differently for the north-facing street and the southeast-facing highline park. Since the street is mostly a source of noise that would distract from the art and the north side of the building offers no opportunities to collect winter sun for heating, the facade becomes a minimalist-plaster covered monolith with a thick composite wall. The minimalism presents a design opportunity to express the global form of the building and is used to embellish the largest parabolic form with a single swooping curve. In the nook created by this curve, the facade is lifted up to revel a glass entrance.

Contrary to the north facade facing the street, the south facade opens onto the highline park, which is much quieter and contains many of the leisurely visitors who would be attracted by an art institution such as The Kitchen. As such, the facade becomes much more open with several large arching parabolic forms. Since the southeast side of the building also includes the sunlight most desirable for heating, the facade includes several large windows that are designed to let in the low winter sun while the overhanging arches extending above them shade the higher summer sun.

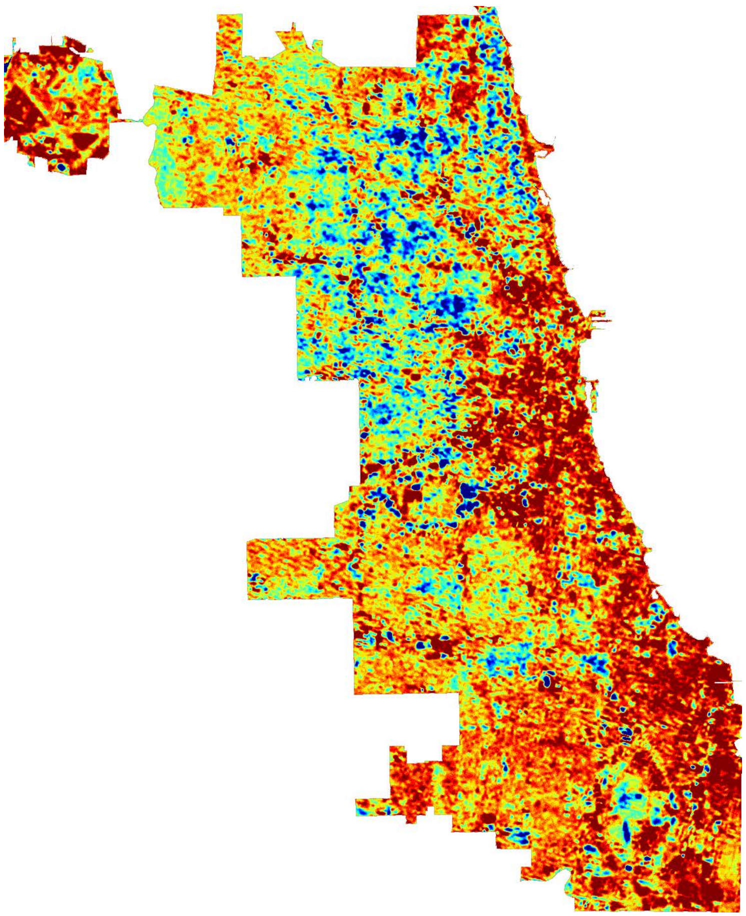
The core of the final design is left largely open with a central daylit gallery that connects the street entrance with the highline entrance via a set of spiral stairs and the third-floor cafe. All of the major art spaces are located off of this central atrium including the black box theater, the white box experimental art space and the music/performance space. The gallery is cradled by three vertical parabolic forms, which carry a stairway in one, an elevator in another and services such as water and electricity in the last.

The light in the central gallery is reflected by the overarching parabolic forms from above, which creates ideal lighting conditions for viewing static art, such as painting and sculpture, without glare. In the winter, this sun becomes more intense as the parabolic forms above capture and focus the direct sunlight onto the thermally massive concrete floor of the gallery. In order to increase the thermal mass of this ground floor, thermally conductive heat pipes are embedded in the concrete and extend 2 meters into the earth below the building. As such, the mass of the earth below the building can participate in the storage of solar heat through the winter in order to keep the space warm through the dark winter night and on cloudy winter days.

The monumental central gallery is experienced after visitors enter from a smaller, more compressed and darker entry chamber.



As visitors look up upon entering the central gallery, they will see the evocative parabolic forms that make up the building's organization logic bathed in sunlight. It is important to note that much of the white diffuse light in this view is not the result of a cloudy sky but is rather the bright white parabolic forms extending beyond the windows to scoop in skylight and reflect it downwards. Accordingly, this condition and light will be experienced in the gallery almost every day, helping draw in visitors and sustain the kitchen as an art institution.



science research

Urban Heat Island

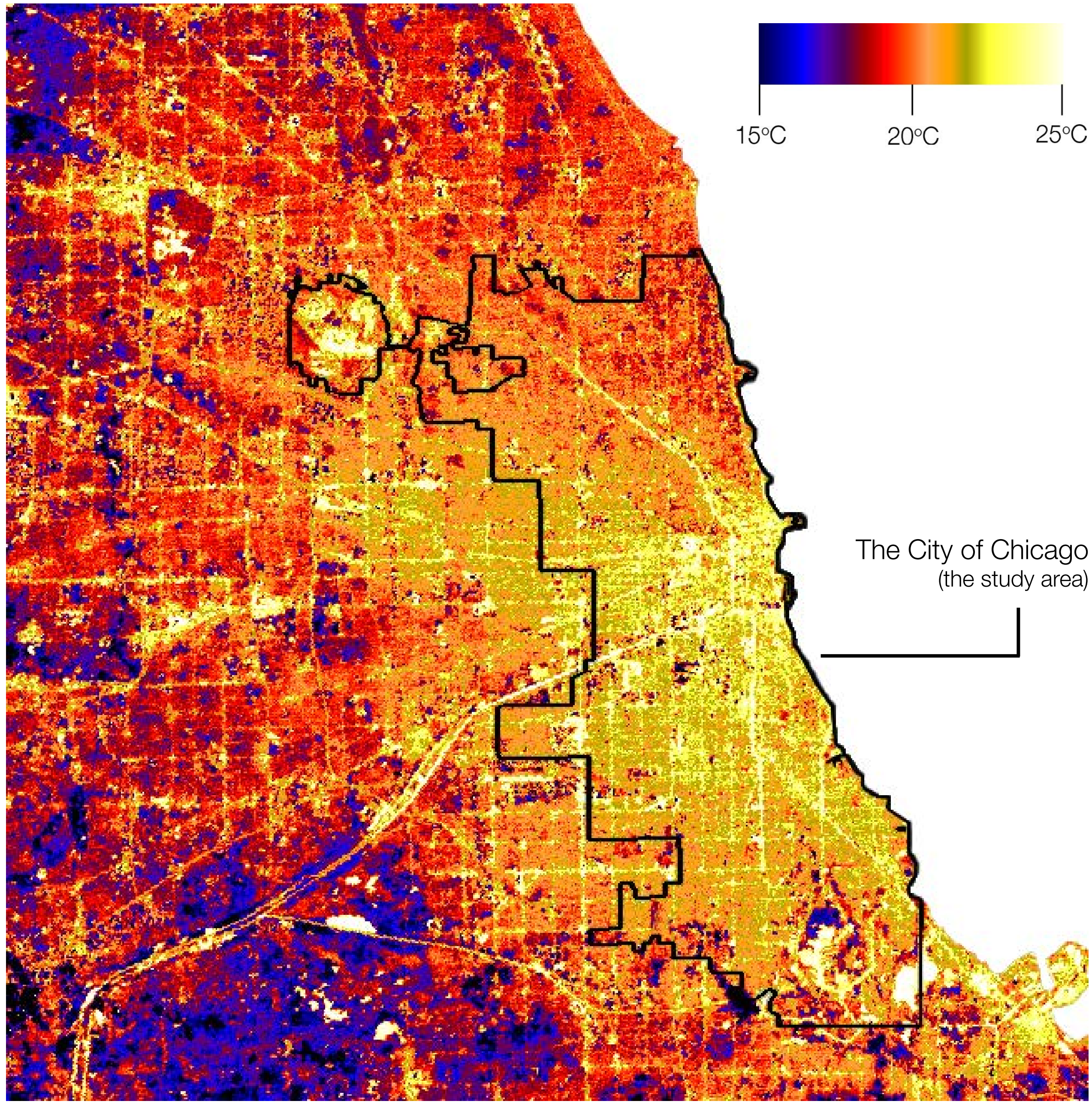
The condition where an urban area is a few degrees warmer than the surrounding rural area.

analysis of chicago urban heat island policies

Chicago Metropolitan Area Temperature (Night)

August 13th, 2007

ASTER



This study is an attempt to analyze the 15-year city-wide heat island reduction campaign of Chicago by observing recent vegetated and reflective surfaces in satellite images of the city. Results show that Chicago's new reflective surfaces since 1995 produced a noticeable impact on the citywide albedo, raising it by about 0.016, while citywide vegetation index (NDVI) increased by 0.007. This finding along with counts of pixels with increased albedo and NDVI suggest that the reflective strategies influenced a larger area of the city than the vegetative methods. Additionally, plots between albedo increase and corresponding LANDSAT temperature change over the test period have linear regressions with steeper slopes (15.7) and stronger linear correlations (0.33) than plots between NDVI increase and temperature change (8.9 slope, 0.17 correlation). This indicates that the albedo increases produced greater cooling than the NDVI increases. Observation of aerial images confirmed that typical instances of efforts to increase albedo, such as reflective roofs, produced stronger cooling than common instances of vegetation efforts, such as green roofs, street trees and green spaces.

Employer - Yale University Center for Earth Observation
Role - First Author (for the study's publication)
Duration - 1 year
Date - Spring 2010 - Spring 2011

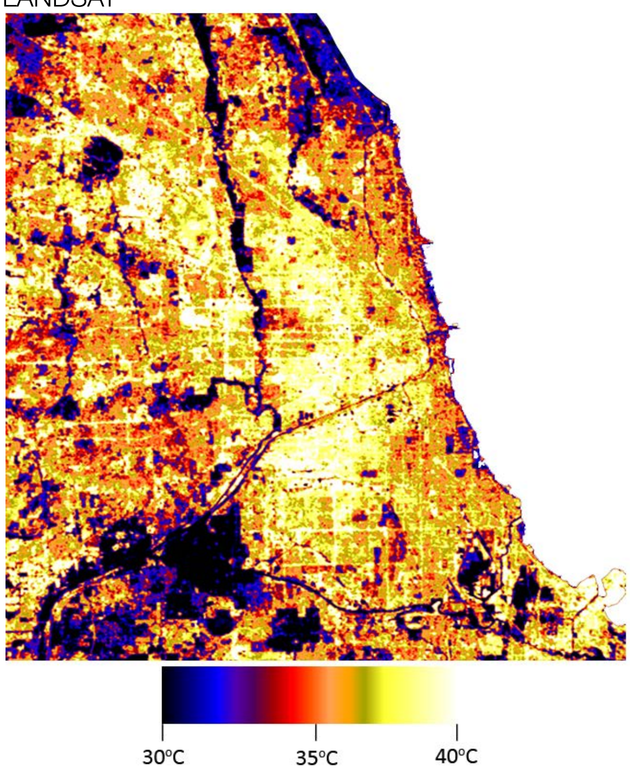
Since the Great Chicago Heat Wave of 1995, the city has implemented a number of localized efforts to combat its urban heat island, indicated by the blue areas in the image to the right.

Methods of Combatting Urban Heat Island

1. Increase **vegetated surfaces**, which will evaporate water instead of increasing in temperature.

2. Increase **reflective surfaces**, which will absorb less solar radiation than dark surfaces.

Chicago Metropolitan Area Temperature (Day)
August 3rd, 2007
LANDSAT



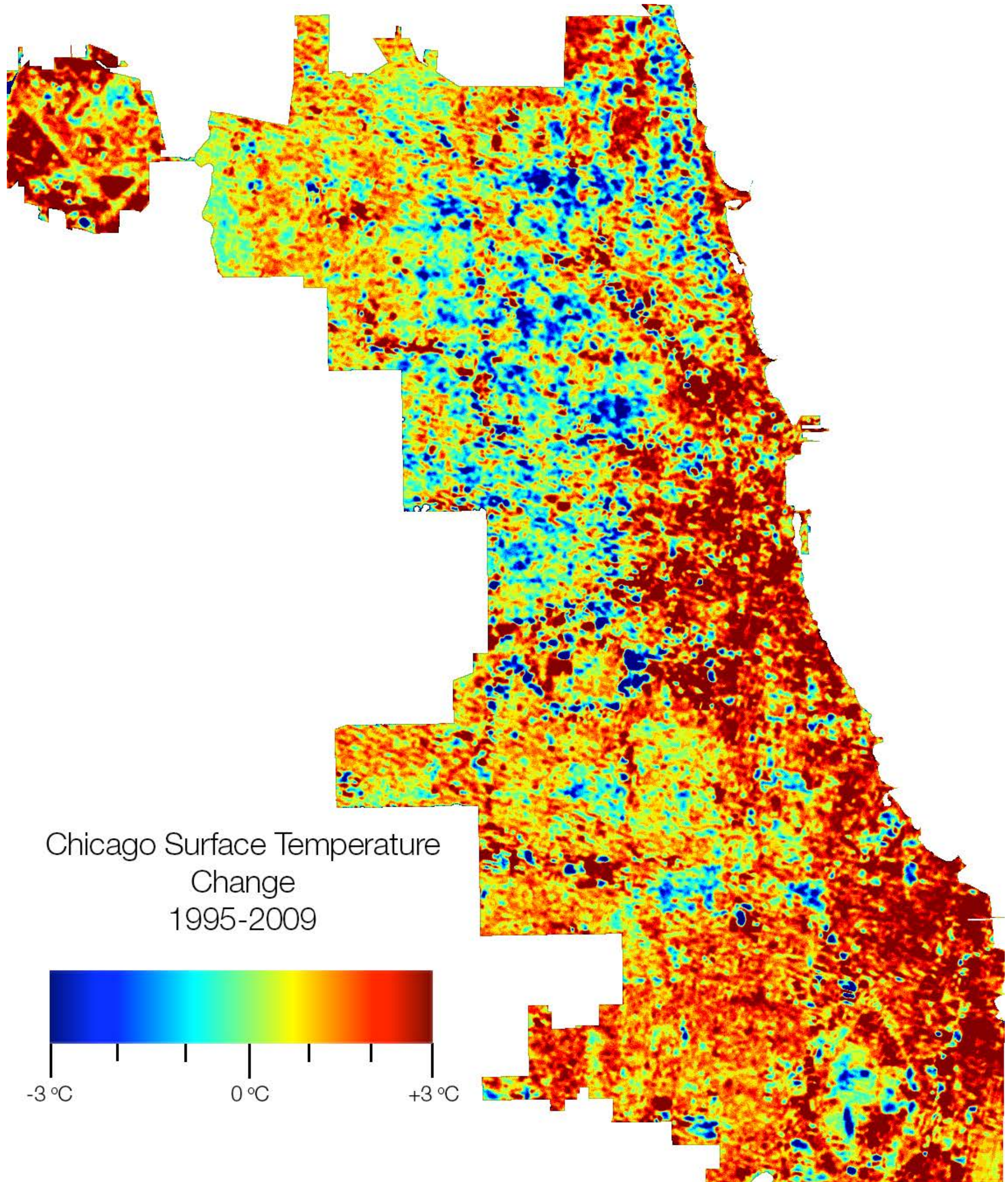
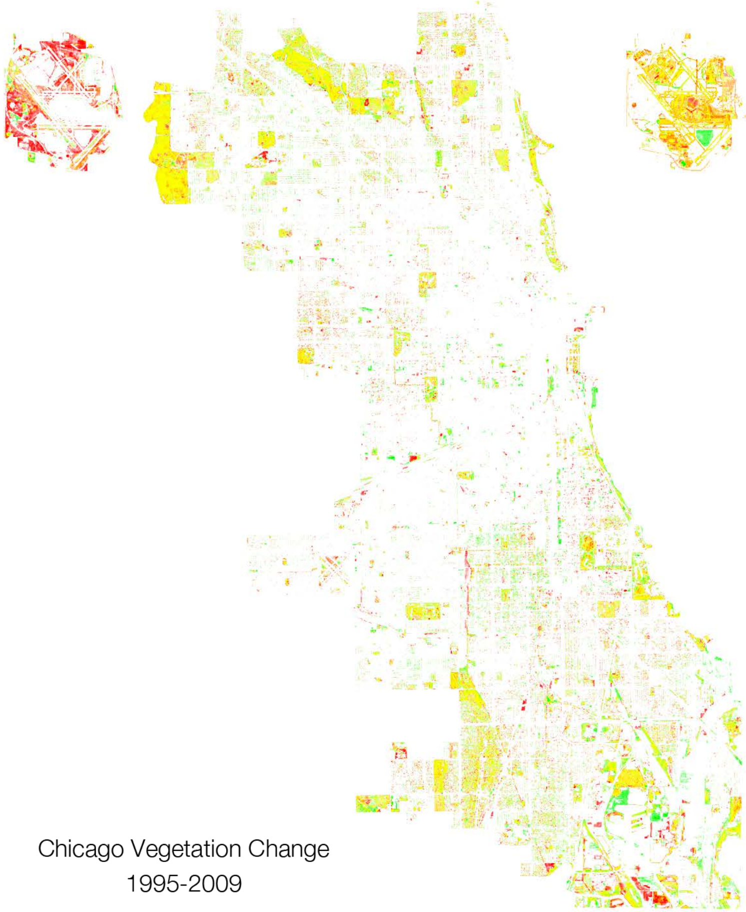


Image made by subtracting values from the LANDSAT temperature band in two images with similar atmospheric conditions.

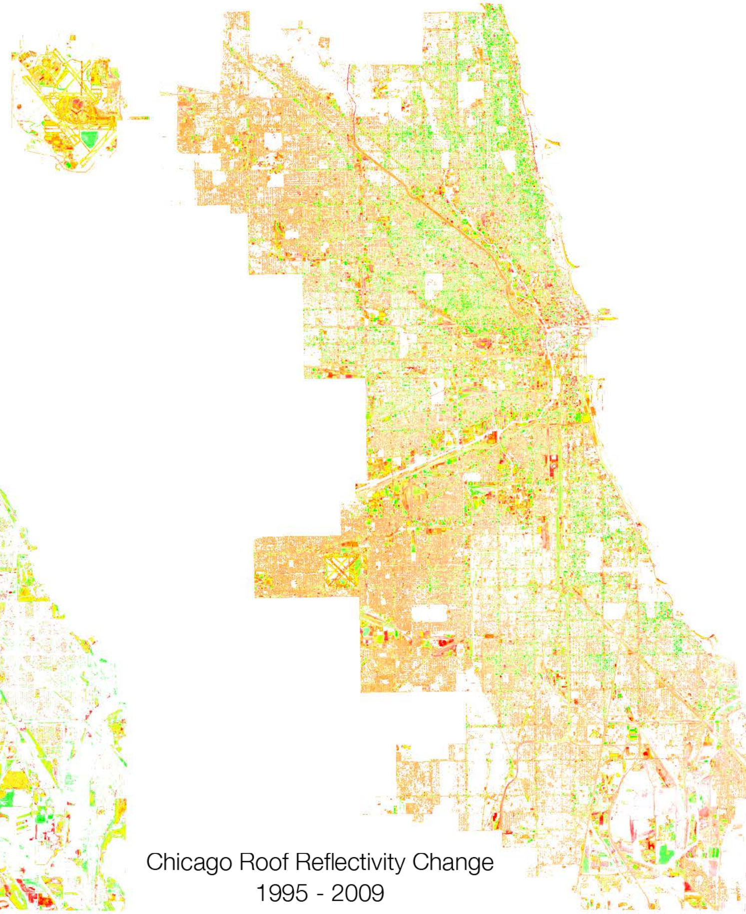


Chicago Vegetation Change
1995-2009

Vegetation Increase

Vegetation Decrease

Vegetation Constant



Chicago Roof Reflectivity Change
1995 - 2009

Reflectivity Increase

Reflectivity Decrease

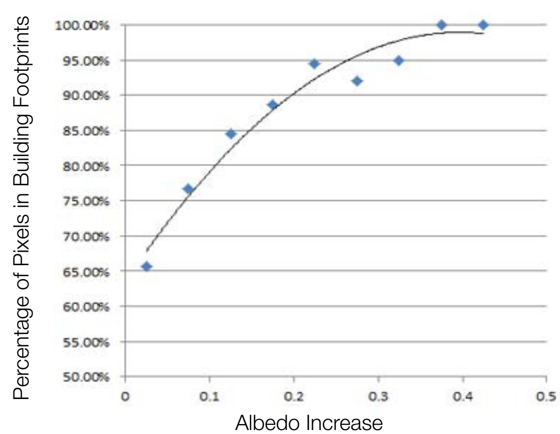
Reflectivity Constant

Dense vegetation appears to have the greatest cooling potential of any surface.

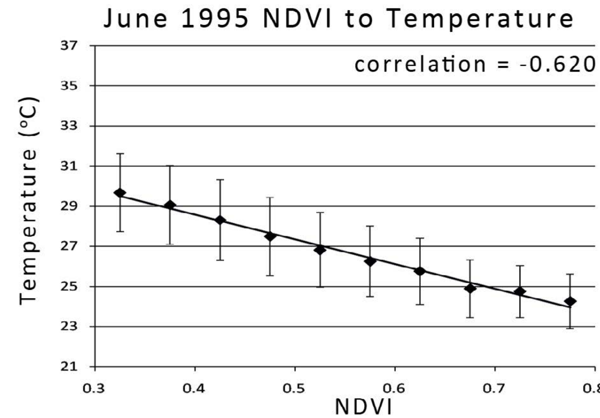
However, Chicago's reflective polices were more effective at cooling than its vegetated ones. Specifically, the reflective roofs seem to be the most effective since most large albedo changes occurred in building footprints.

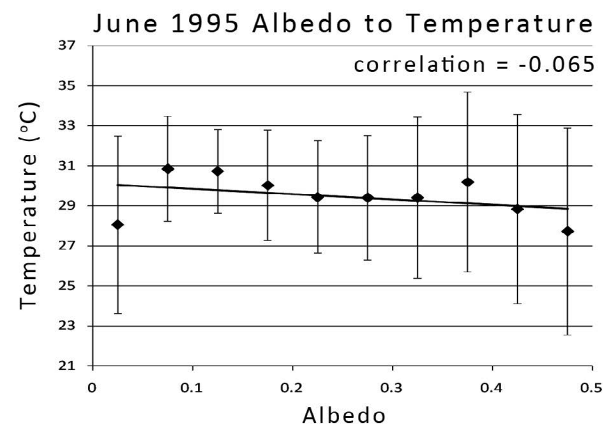
This is probably because the reflective roofs produced the most cooling for the smallest amount of money invested.

Percentage of Albedo Increases in Building Footprints



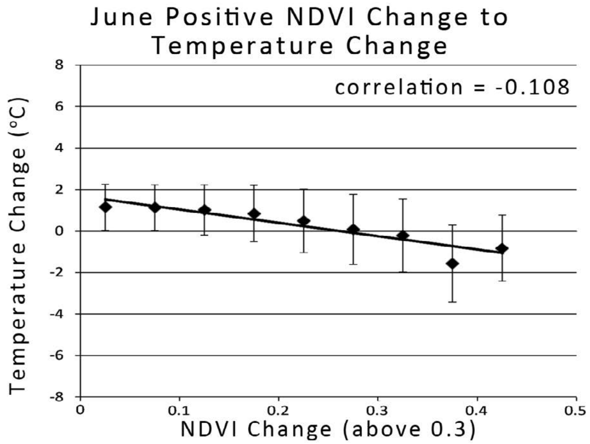
Correlations of NDVI and Albedo to Temperature Within Single Satellite Images

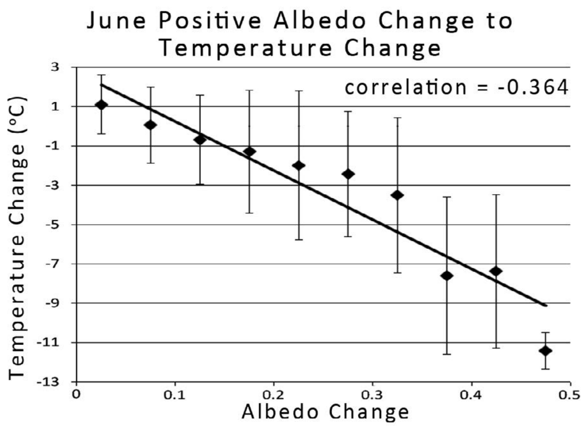




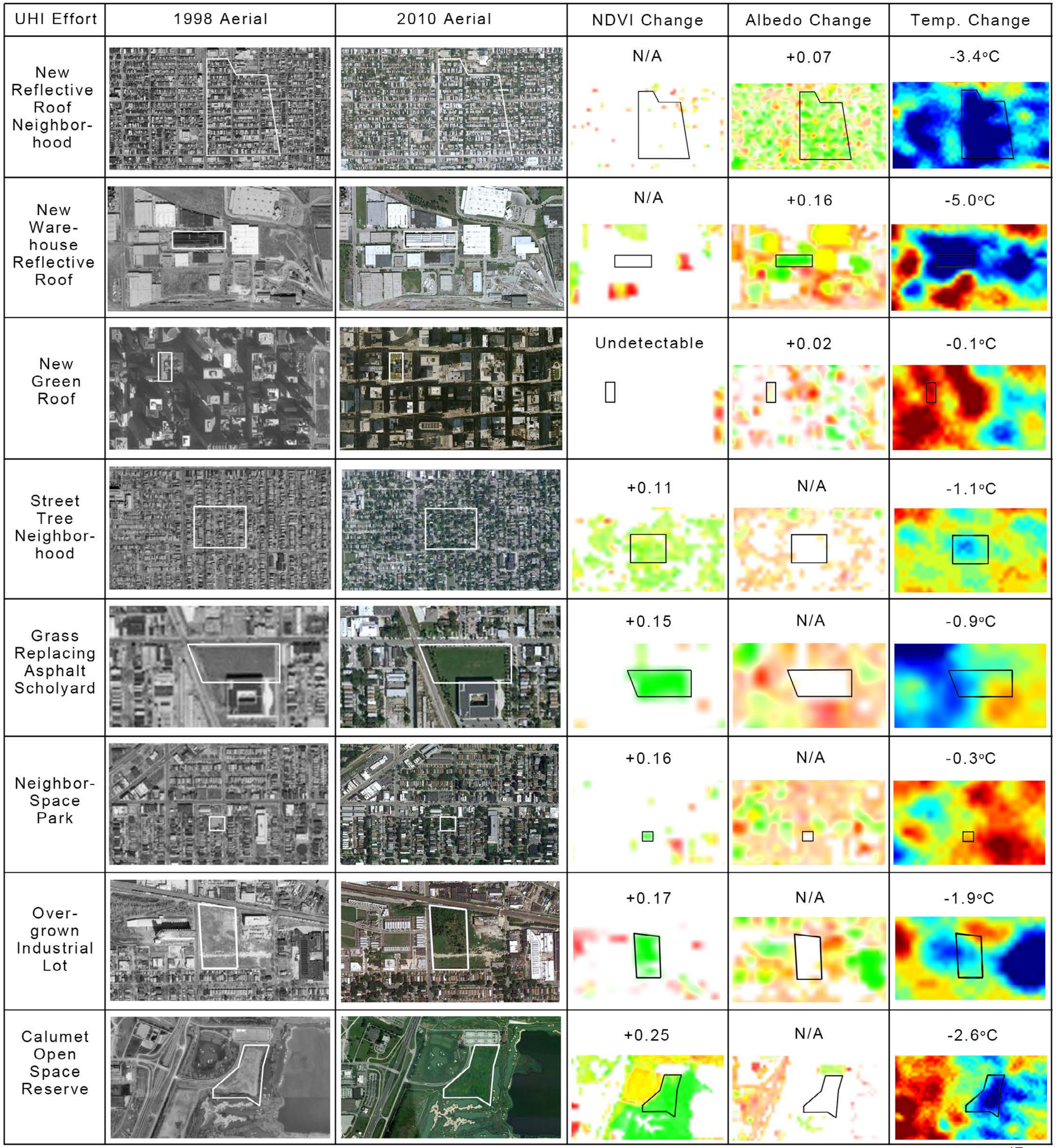
Within single images of the city, densely vegetated surfaces generally correspond to much cooler temperatures than highly reflective surfaces.

Correlations of NDVI and Albedo to Temperature Within Single Satellite Images





However, the increases in Chicago's reflectivity between 1995 and 2009 corresponded to much greater cooling than its increases in vegetation did.



UHI Effort	1998 Aerial	2010 Aerial	NDVI Change	Albedo Change	Temp. Change
New Reflective Roof Neighborhood			N/A	+0.07	-3.4°C
New Warehouse Reflective Roof			N/A	+0.16	-5.0°C
New Green Roof			Undetectable	+0.02	-0.1°C
Street Tree Neighborhood			+0.11	N/A	-1.1°C
Grass Replacing Asphalt Scholyard			+0.15	N/A	-0.9°C
Neighbor-Space Park			+0.16	N/A	-0.3°C
Overgrown Industrial Lot			+0.17	N/A	-1.9°C
Calumet Open Space Reserve			+0.25	N/A	-2.6°C

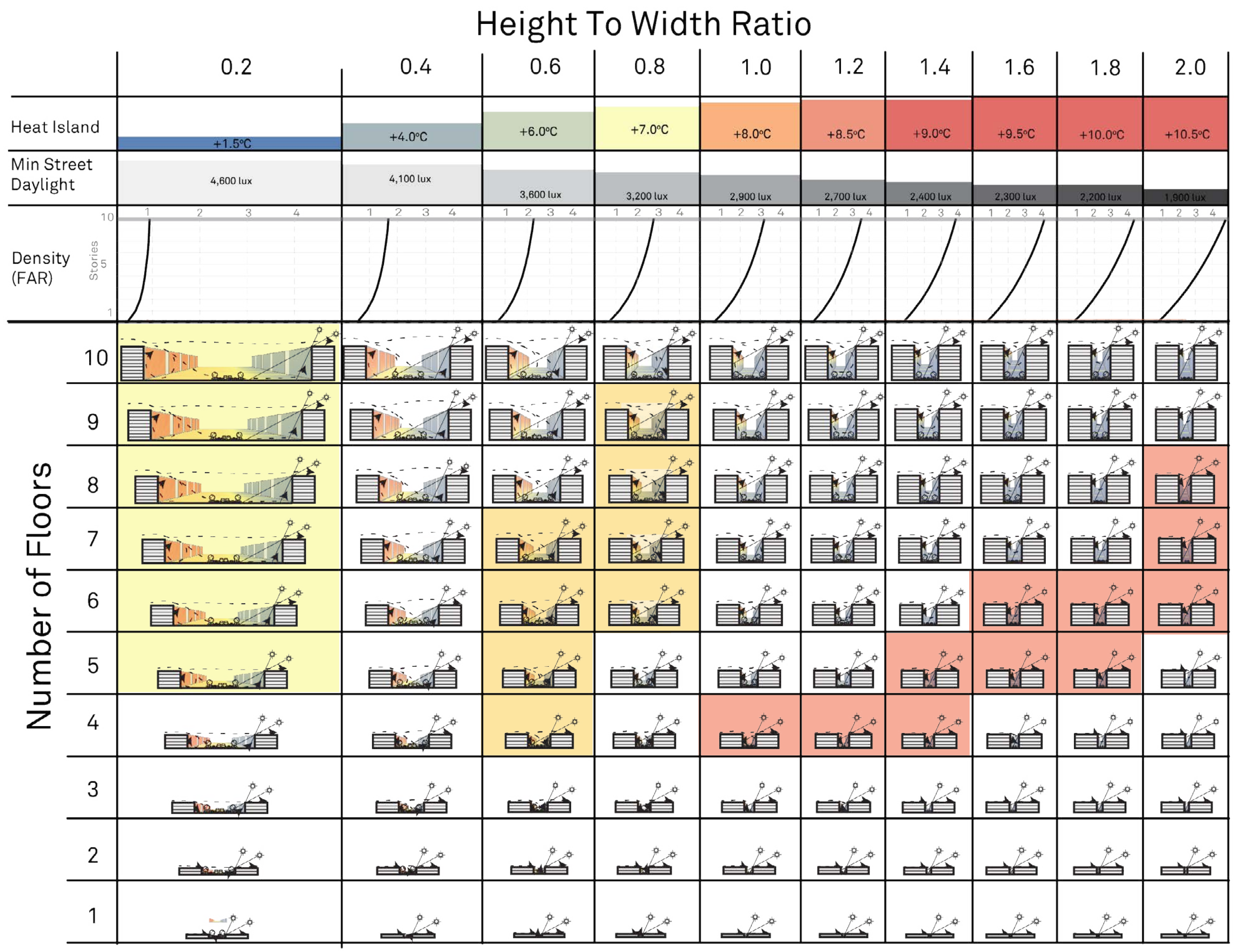
urban thermal diversity calculator

For decades, the urban climatology community has sought to develop guidelines for planners in order to help mitigate the urban heat island effect. However, to this day, many of their recommendations remain ignored as urban form continues to be driven by climate-insensitive economic forces and political bodies.

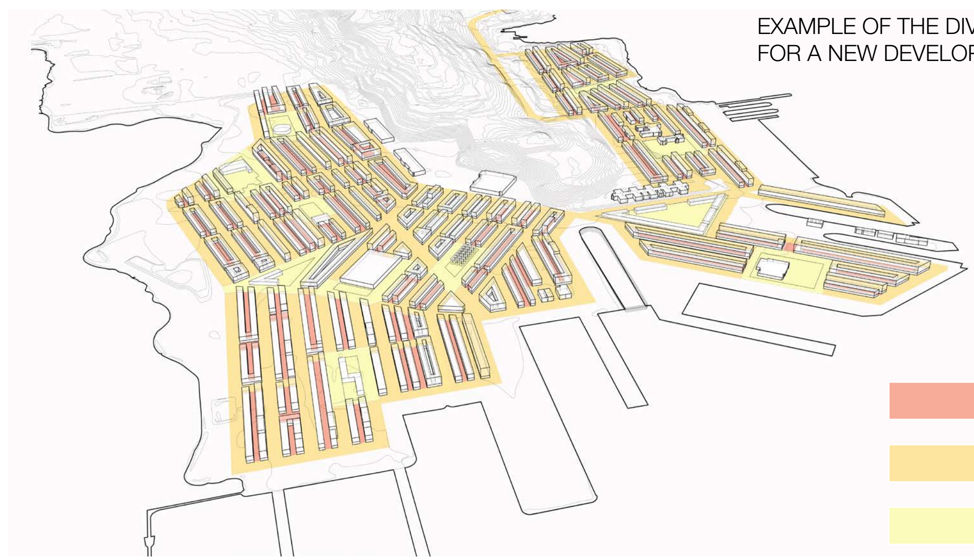
From the perspective of an architect or planner, a key shortcoming of the recommendations given by urban climatologists is that their climate models often involve an oversimplification of the urban landscape, which is necessary to get the models to run in reasonable time periods on today's computers. As a result, many of the recommendations that climatologists give tend to be simplistic such as “the ratio of building height to street width should be between 1.0 and 0.4.” In addition to being difficult to follow, these recommendations fail to recognize that some of the most successful and continually populated urban areas have a diversity of public space types and urban microclimates.

The urban thermal diversity calculator recognizes this value and uses climate models along with solar radiation studies to recommend at least three types of spaces planners might use to shape zoning in a given climate. Each of the spaces is designed to be cooler or warmer at a certain time of day or year, ensuring that there is always a public space that is most desirable. A good balance of the three ensures reduced heat island on a large scale with valued microclimates on the small scale.

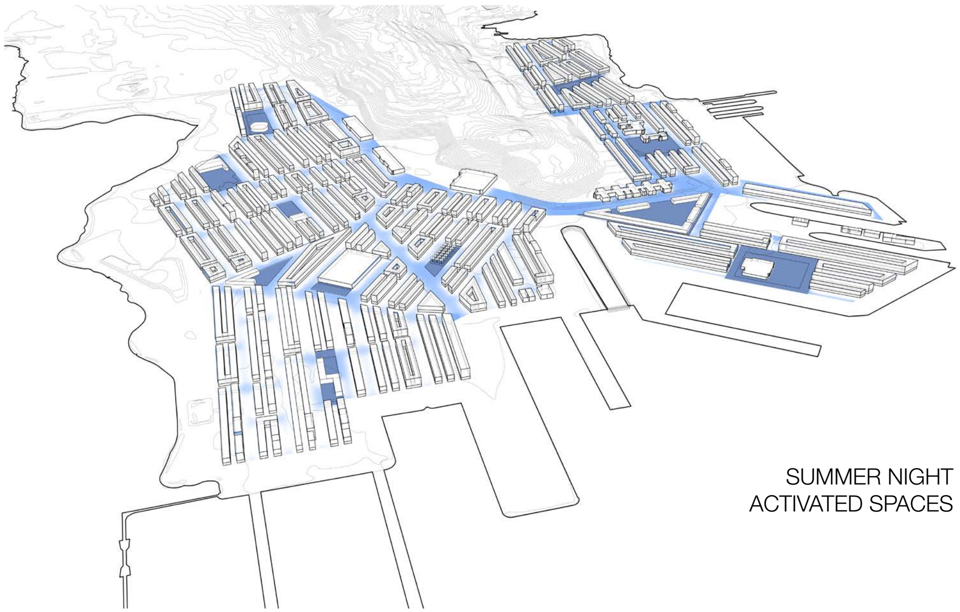
Project Type - Academic
Employer - MIT Building Technology Department
Duration - 0.5 years
Date - Winter 2013 - Summer 2013



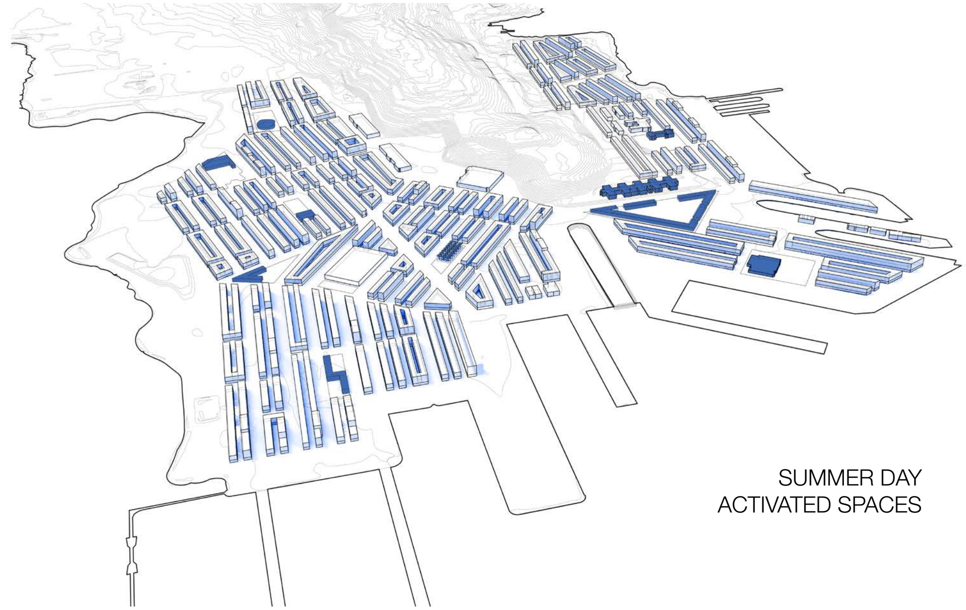
EXAMPLE OF THE DIVERSITY CALCULATOR FOR A NEW DEVELOPMENT IN SAN FRANCISCO



ALLEYWAYS / COURTYARDS
BOULEVARDS
PLAZAS / PARKS



SUMMER NIGHT
ACTIVATED SPACES



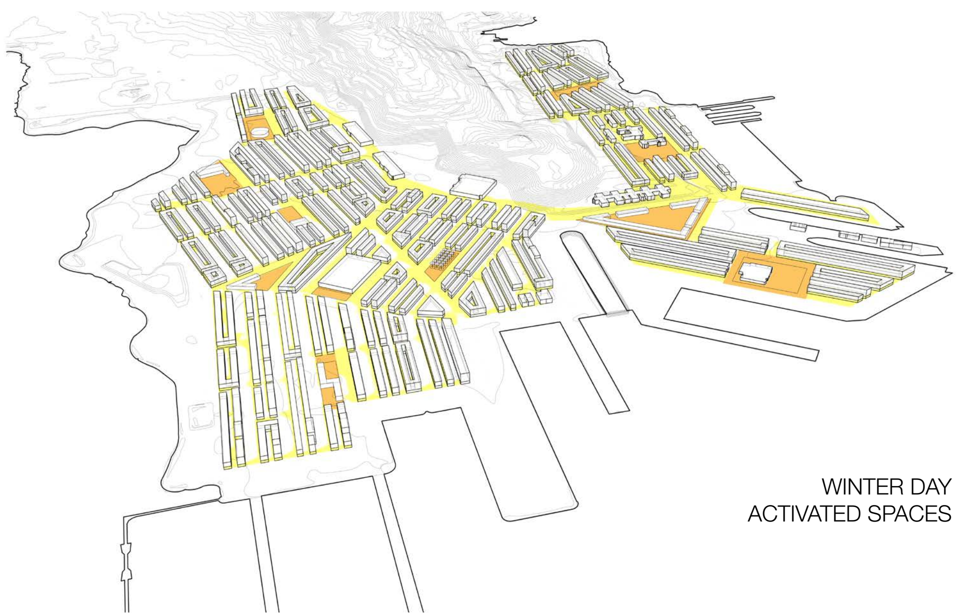
SUMMER DAY
ACTIVATED SPACES

Following the traditional recommendations of urban climatologists, wide streets and parks act as important heat sinks on hot summer nights, cooling down the heat island and providing enjoyable microclimates.

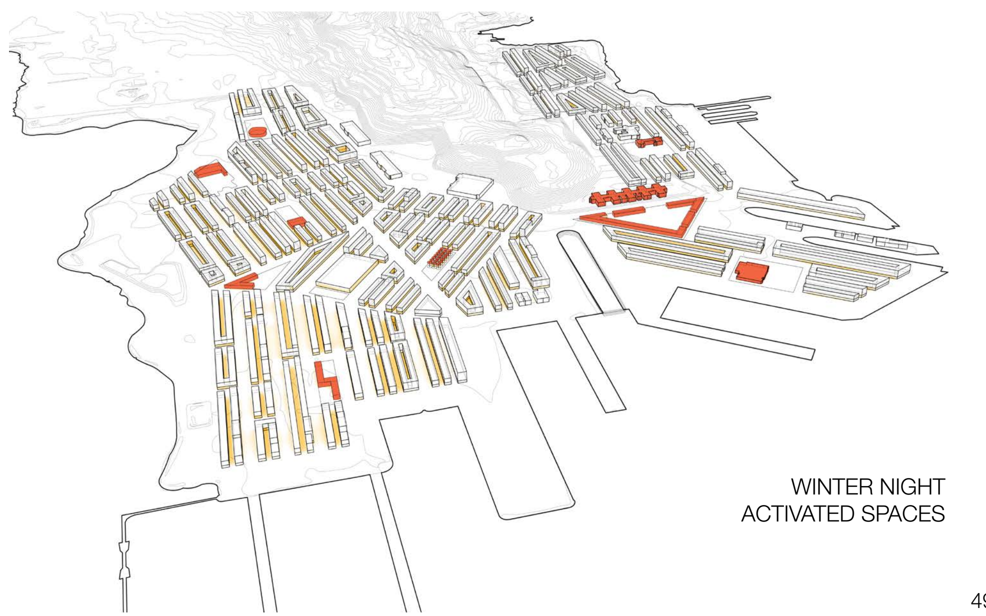
These wide boulevards and parks also get a lot of appreciation in colder months, when people often sit in the sun to keep themselves warm.

A narrow street might trap radiation, block wind, and increase the heat island effect in the evening but the shade provided by the tall buildings is a huge asset at the hottest part of a summer day.

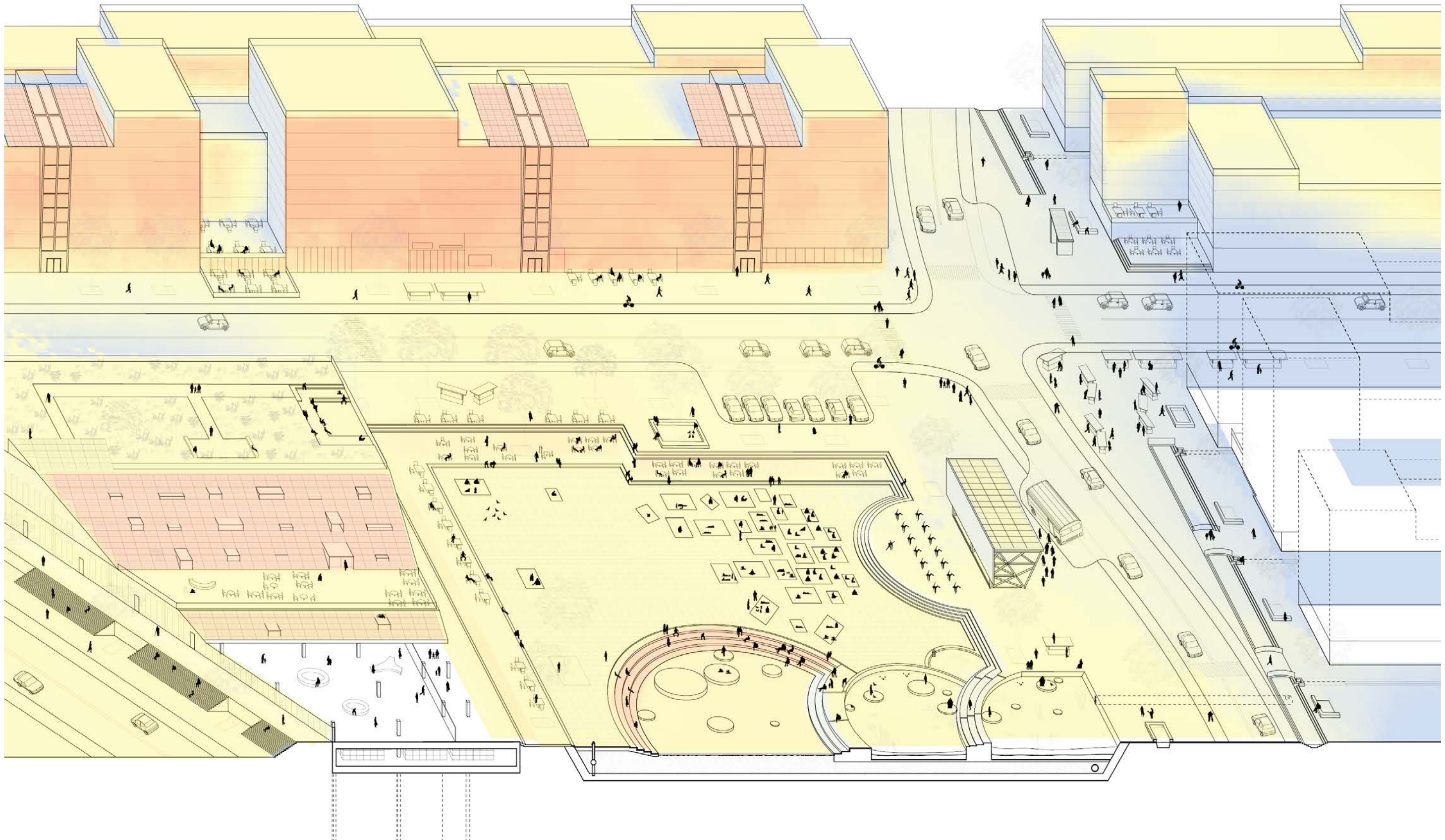
Also, many climates have a part of the year where the heat island effect is desirable and the heat trapped narrow streets helps save winter heating energy. A good example is the winter night of San Francisco.

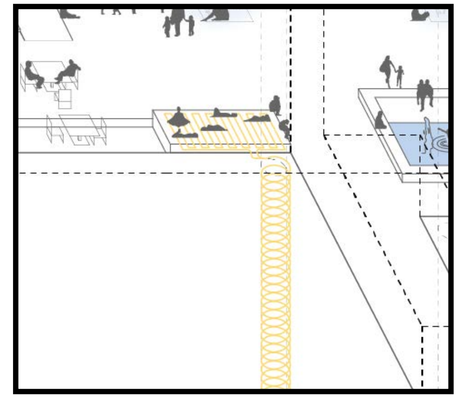


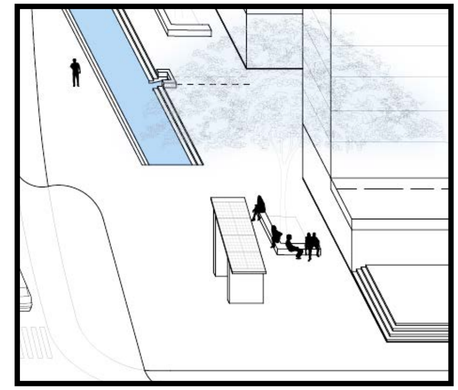
WINTER DAY
ACTIVATED SPACES

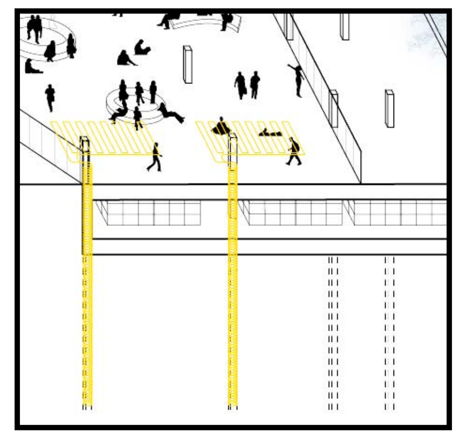


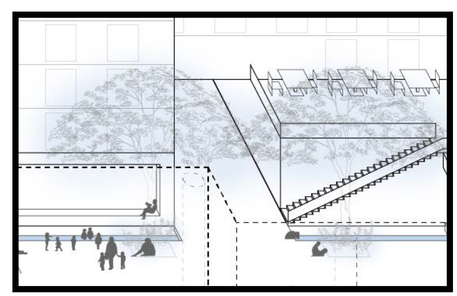
WINTER NIGHT
ACTIVATED SPACES



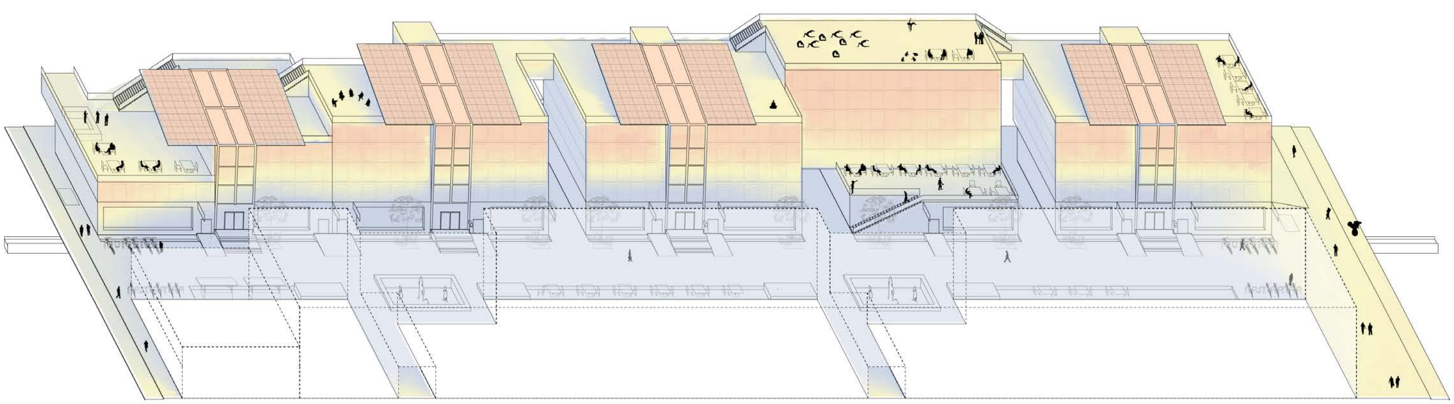


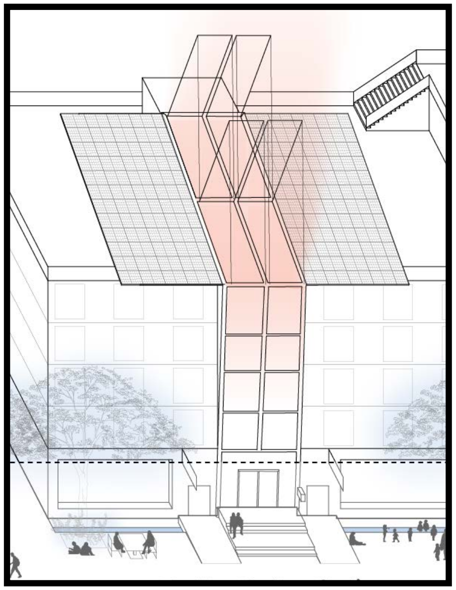


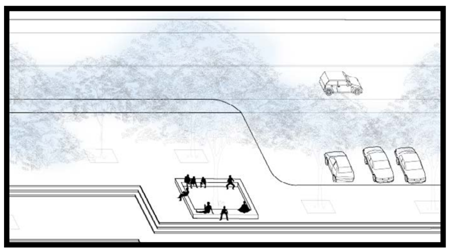


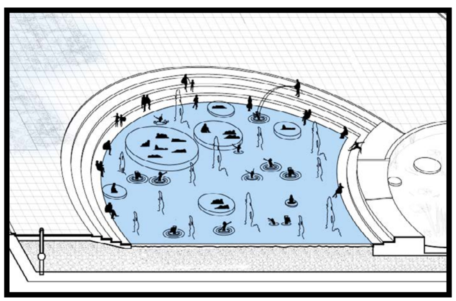


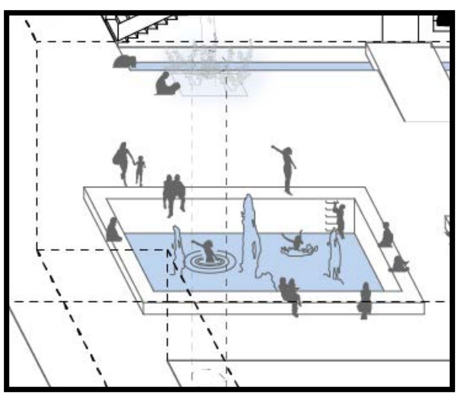
Radiation studies of a typical winter day show that open plazas and boulevards are needed to make people comfortable and attract them out of their homes. The choreographing of people into these spaces also identifies spots where strategies such as thermally active benches or deciduous trees could be deployed to further extend the use of outdoor spaces into colder months.

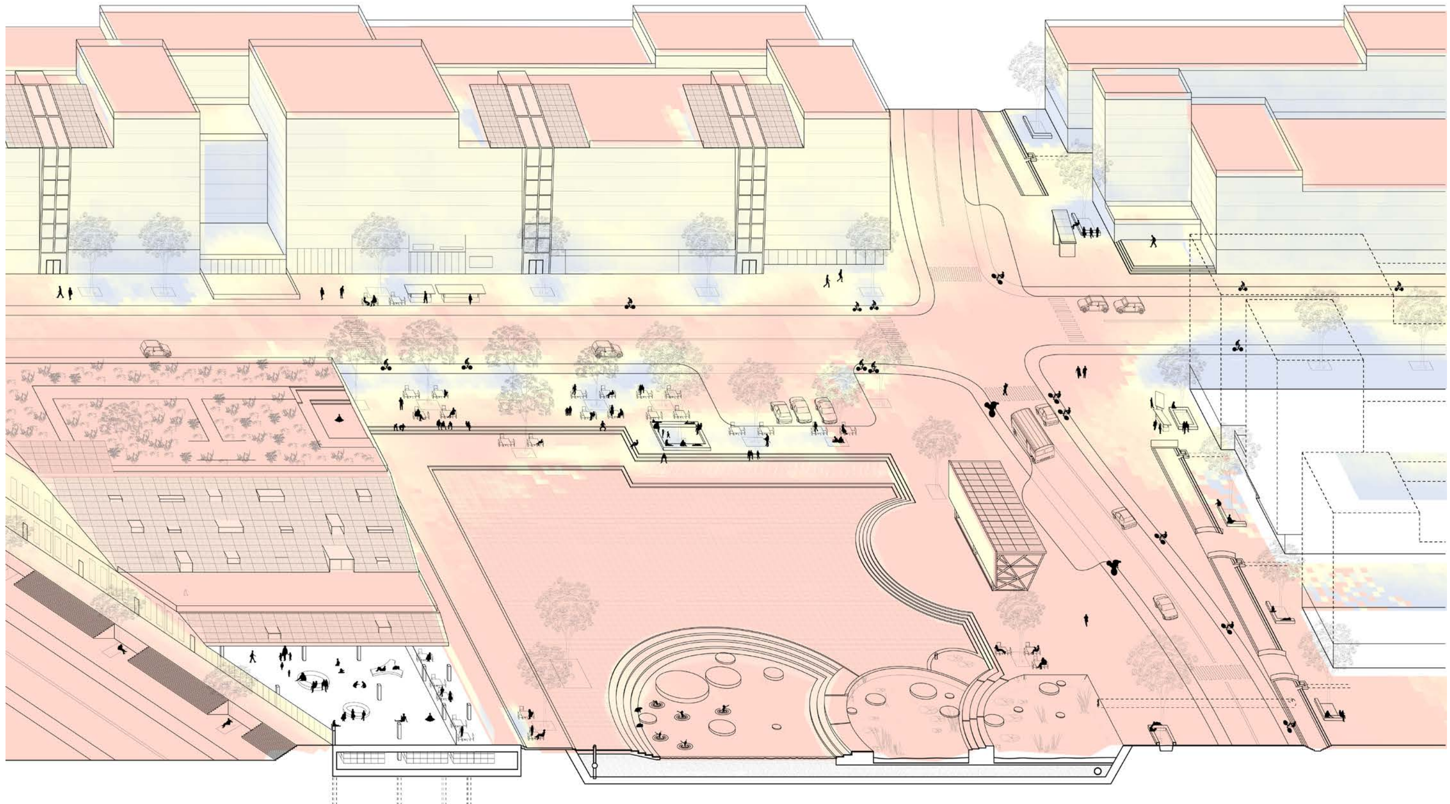




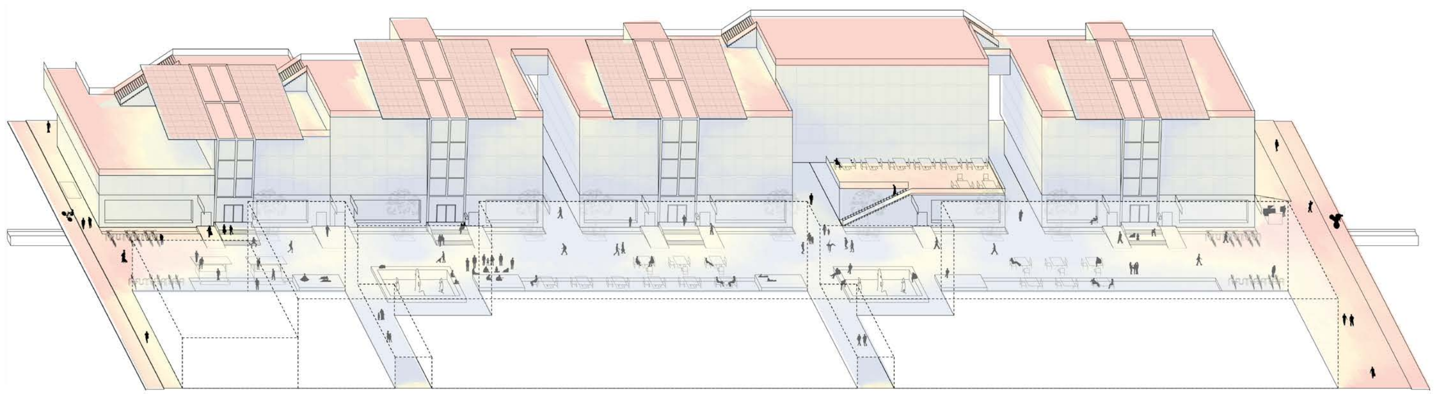








Radiation studies of a typical summer day show that narrow streets are critical to ensuring outdoor comfort and use of outdoor space in these times. By keeping the buildings passively ventilated with operable chimney/stairwells and attracting people outside in these hotter conditions, residents remain in contact with their neighbors, which many studies have shown is just as effective for surviving a heat wave as an air conditioning unit. The choreographing of people into narrow streets also identifies critical spots where strategies such as water features could be deployed to help make residents more comfortable and healthy in these times.



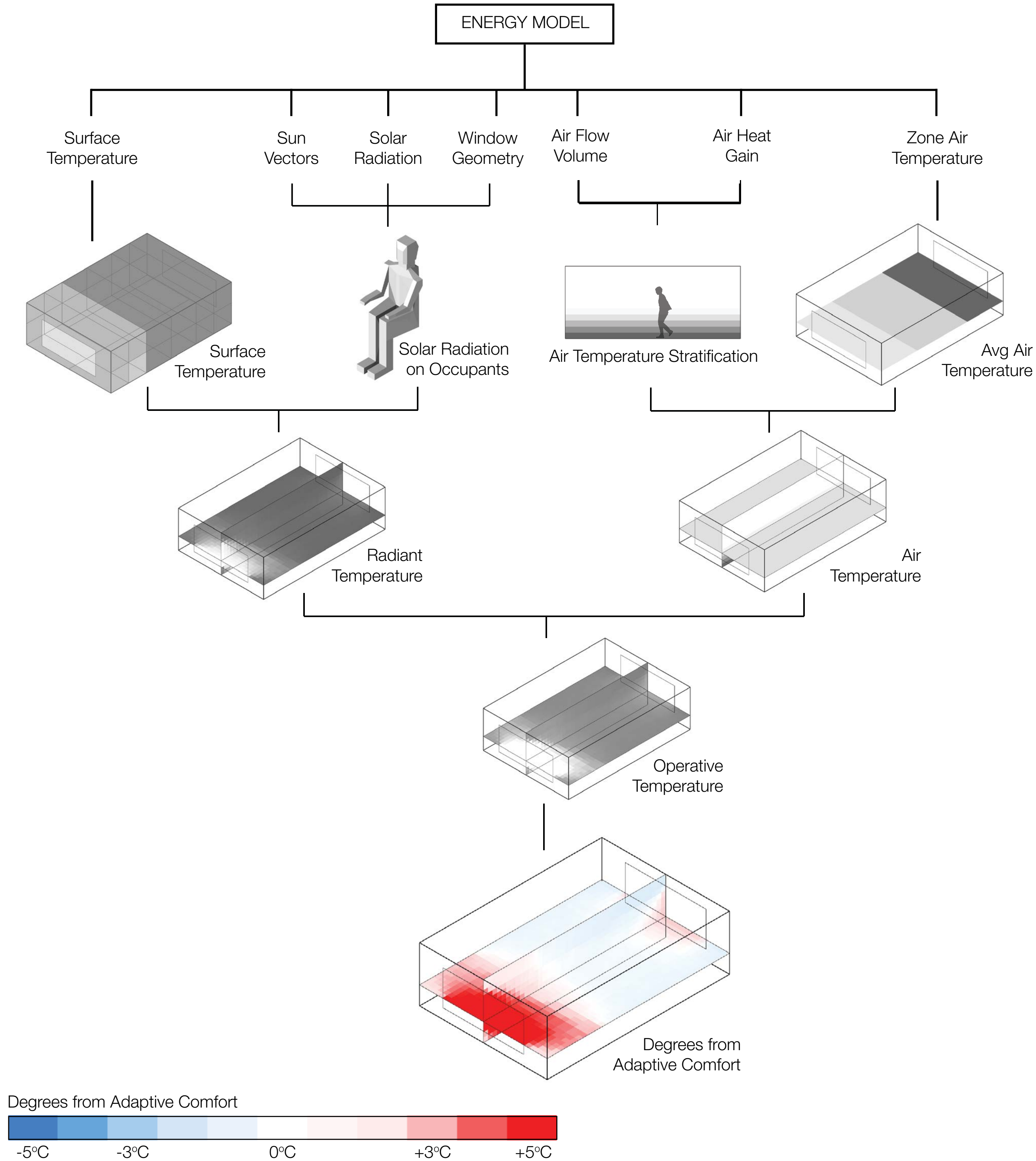
architectural microclimate maps

Oftentimes in contemporary practice, we address issues of energy with an additive approach, seduced by new products and gadgets that we simply throw into our wasteful architectural contraptions instead of exploiting the given rich complex interactions between occupants, climate, and materials.

Our few attempts to synthesize these three complex phenomena occur almost exclusively in mathematical matrices of computational energy models, which, after pulling these three terms together through the universalizing first law of thermodynamics, simply spew out separate streams of numerical data. We rarely take the extra step of integrating these separate streams of data into visual formats that can be understood and interpreted by humans, inducing the much more important synthesis in the minds of a design process's decision-makers. As such, our current computational tools that have the power to inform us of these three incredibly complex phenomena, remain merely analytical, passively accepting a set of conditions as inflexible instead of serving an instrumental role by actively informing the design process.

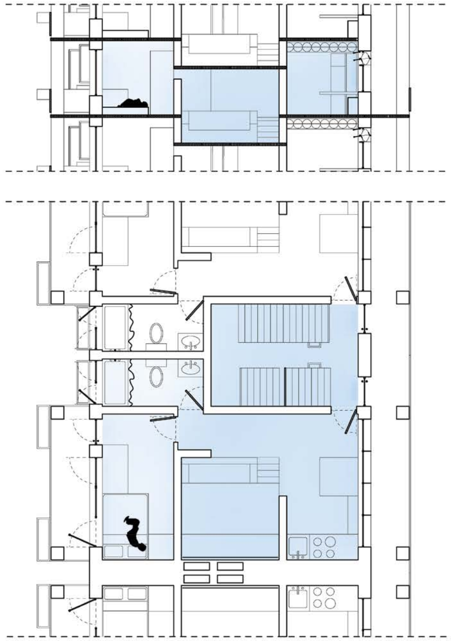
To assist in the use of energy models towards an instrumental end, a method was developed to synthesize their results into thermal microclimate maps. Such maps provide feedback to the design and are used to help locate indoor program and script the patterns of occupant behavior.

Project Type - Academic
Duration - 1.5 years
Date - Winter 2014 - Summer 2015



NATURALLY VENTILATED APARTMENT - LOS ANGELES - AUGUST

3 AM



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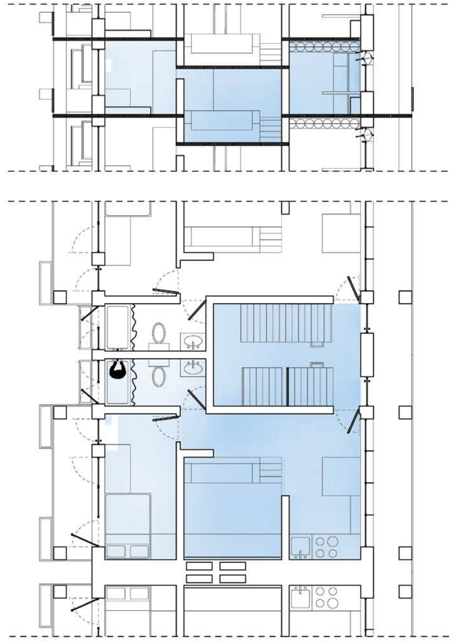

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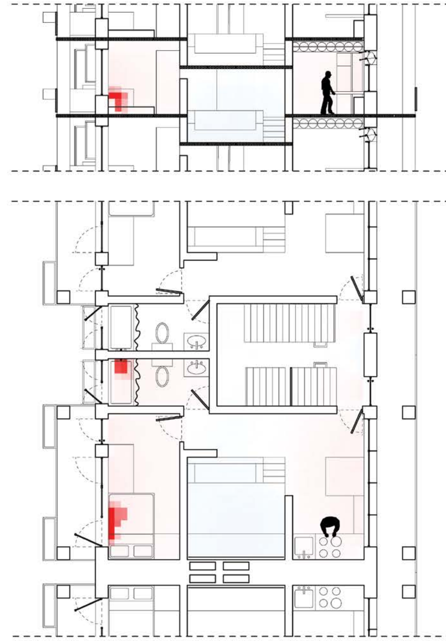
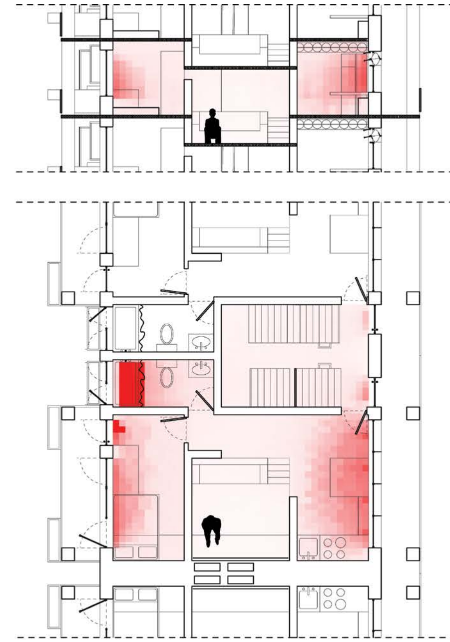


12 PM



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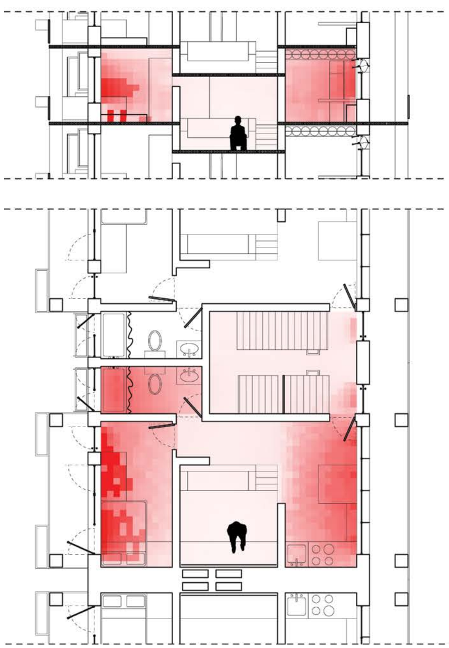

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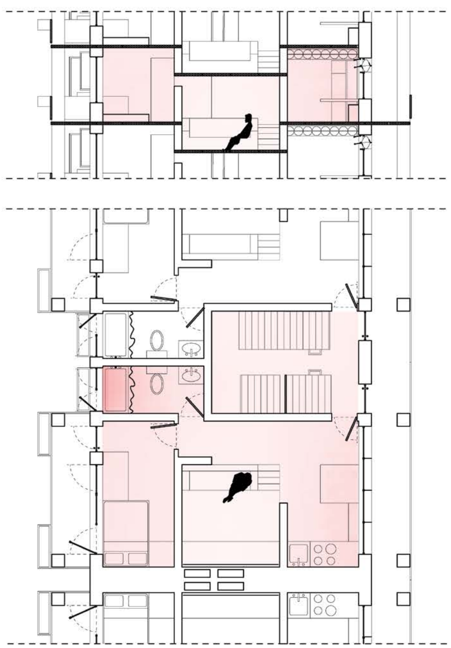

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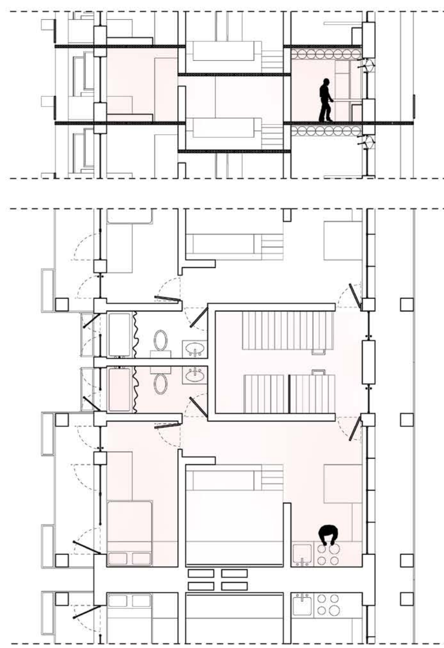

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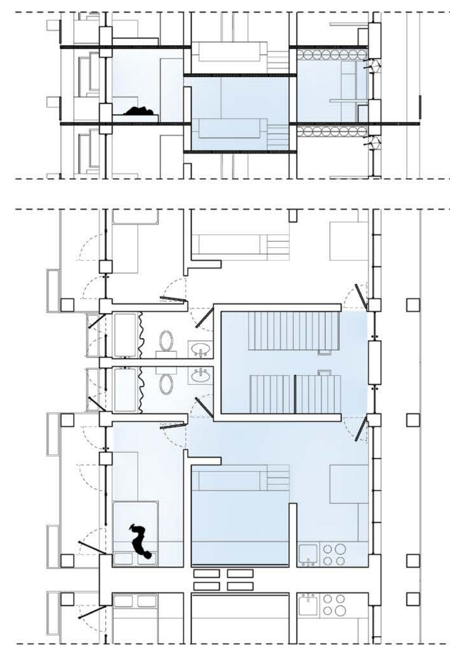
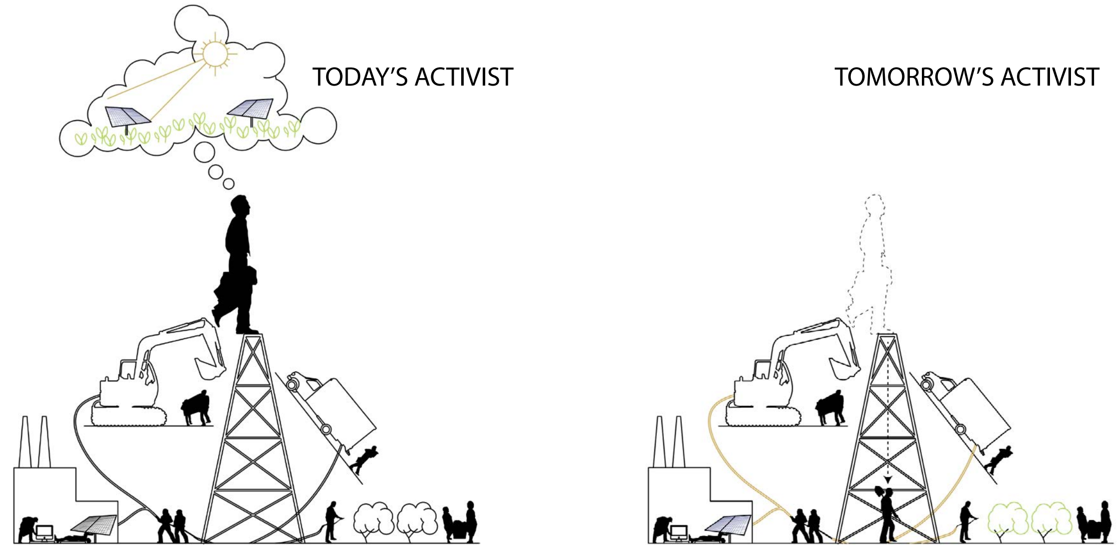


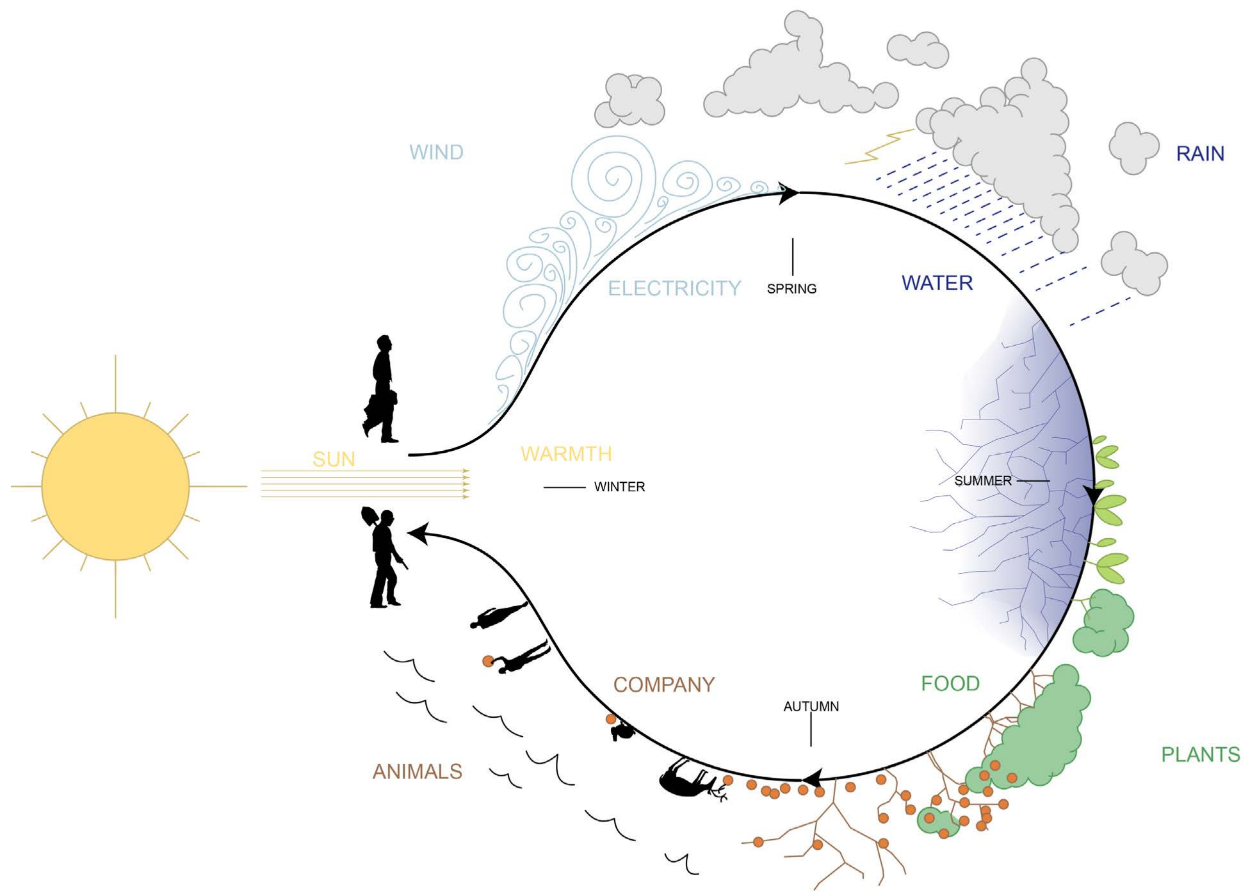
metabolic agricultural calculator

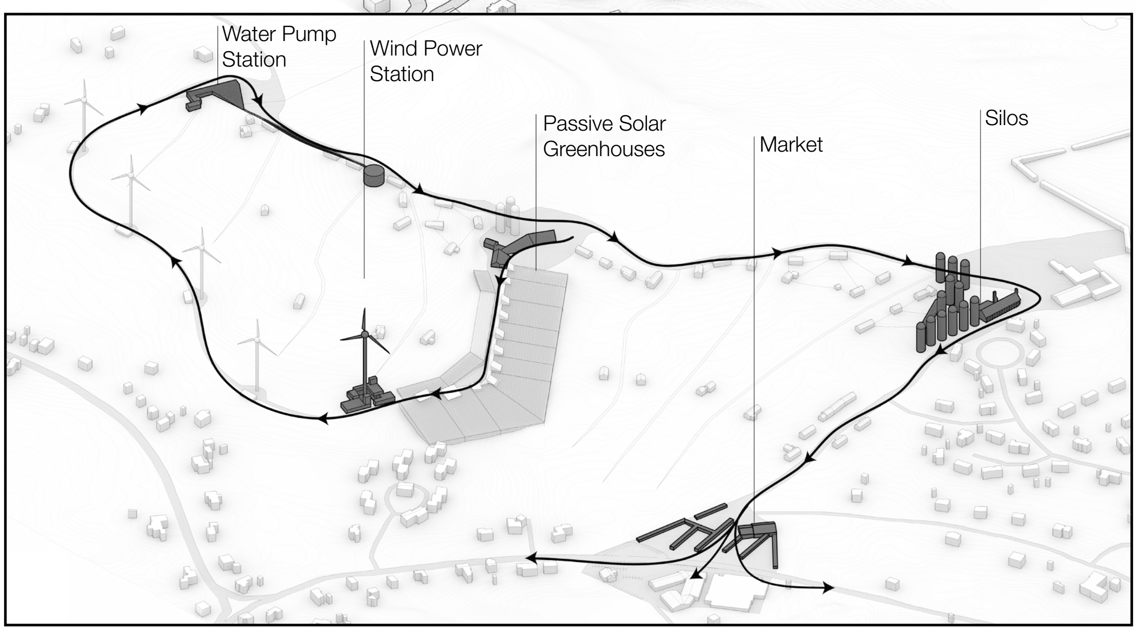
While today's climate activism is badly needed, there is a sense that many activists in the developed world suffer from a lack of understanding of the infrastructure and economic systems that support their lifestyle. To address the situation, this project proposes a farm internship program that could put such activists in touch with the labor equivalent of energy and empower them with a means of enacting meaningful physical change. In such an internship, participants would move through an annual cycle in which each season is focused on harvesting a different type of energy: winter - sun for warmth, early spring - wind for electricity, late spring - water for drinking, summer - plants for food, autumn - people for company.

To help plan the development of the internship program and express its values, an energy model was developed called the Metabolic/Ambient Comparison Engine (MAC-E). By using the metabolic rate of the human being as its unit system and tracing the flow of energy from incoming sun through the land uses to the human, MAC-E embodies the ideals of the internship program stated above. After performing a number of analyses on a terrain surface for a proposed farm internship site and using a corresponding climate file for the site, MAC-E ultimately outputs a maximum number of people that can be supported on the land for given input land uses and energy harvesting infrastructure. Also included is the limiting factor of human support (ie. electricity, food, or biofuel) and a capital cost estimate of the development. Lastly a number of visualizations are output to help users understand how land uses might manifest themselves on the terrain in order to maximize land productivity.

Project Type - Academic
Duration - 0.5 years
Date - Fall 2013 - Winter 2014



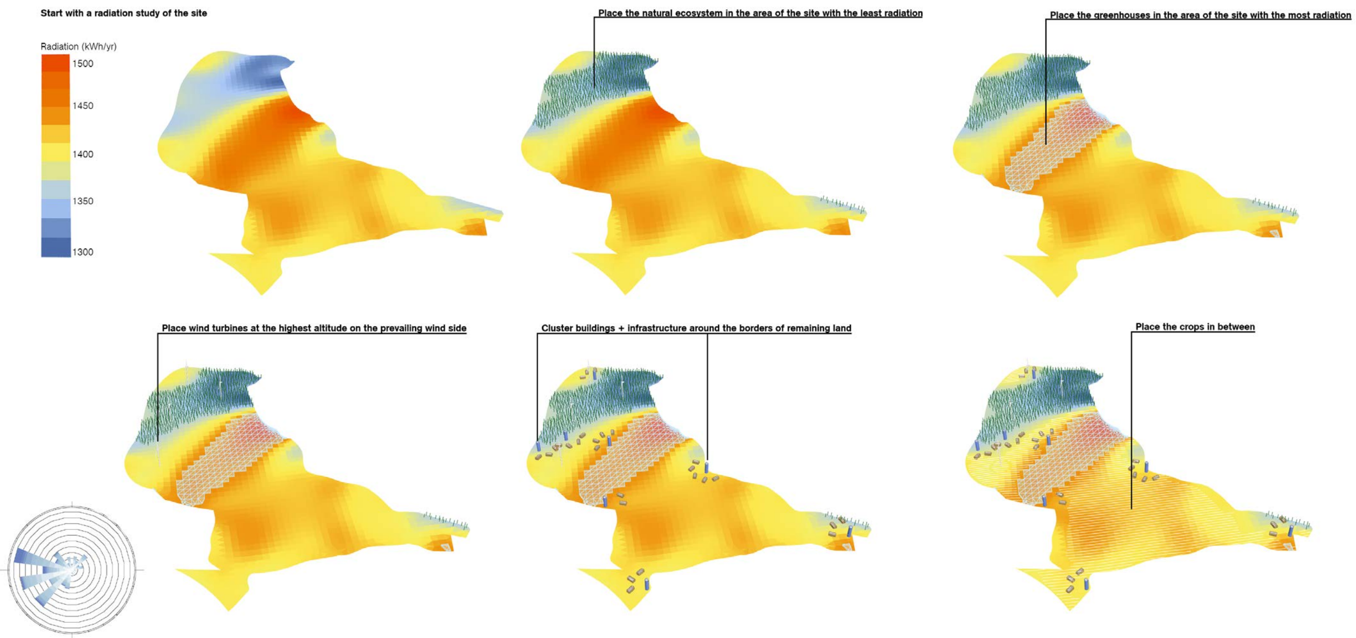


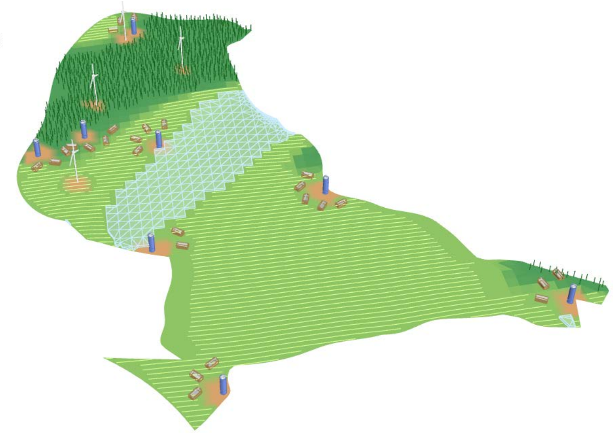


A variety of strategies are used to keep the farm running year-round including passive solar greenhouses that maintain a small amount of production in the winter and a market that continues to sell goods after the majority of crops have been harvested.

GROWING SEASON WITHOUT GREENHOUSES

GROWING SEASON WITH GREENHOUSES

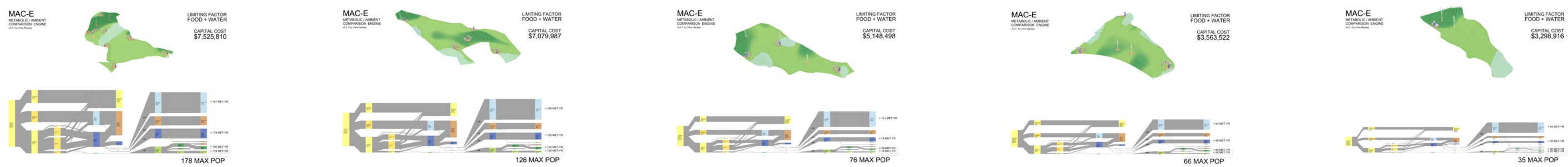




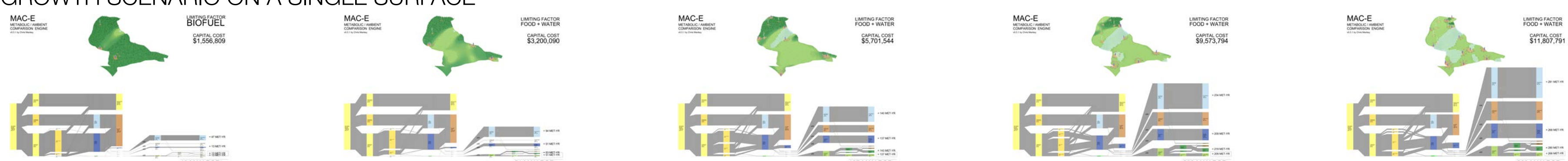
In order to construct a visualization of how land uses might manifest themselves on the site to maximize productivity, MAC-E starts with an annual radiation study since the sun is the primary source of energy on the land and is the driving factor of the model. Any undisturbed natural ecosystem is placed in the area of the site with the least radiation since it is often more productive to use the sunlit ground for crops. Passive greenhouses are placed in the area of the site with the most radiation since the increased sunlight helps ensure that these areas stay as warm though the winter. Wind turbines are placed in the higher altitudes of the site on the side of the prevailing winds. Buildings are placed on the outskirts of the remaining available land and crops are placed in between.

POSSIBLE SCENARIOS WITH MAC-E

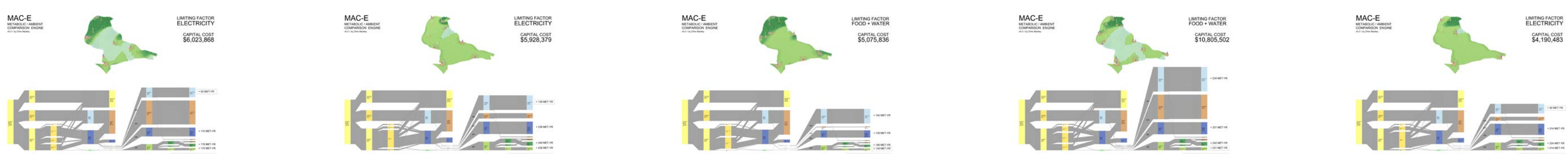
DIFFERENT INPUT TERRAIN SURFACES



GROWTH SCENARIO ON A SINGLE SURFACE



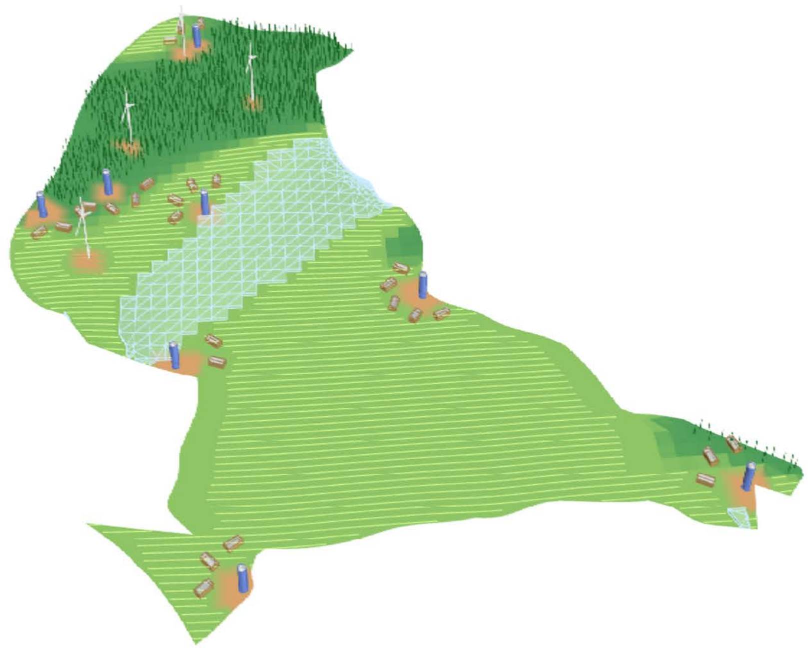
GENERATIVE ALGORITHM OPTIMIZING THE MAXIMUM SUPPORTED POPULATION



MAC-E

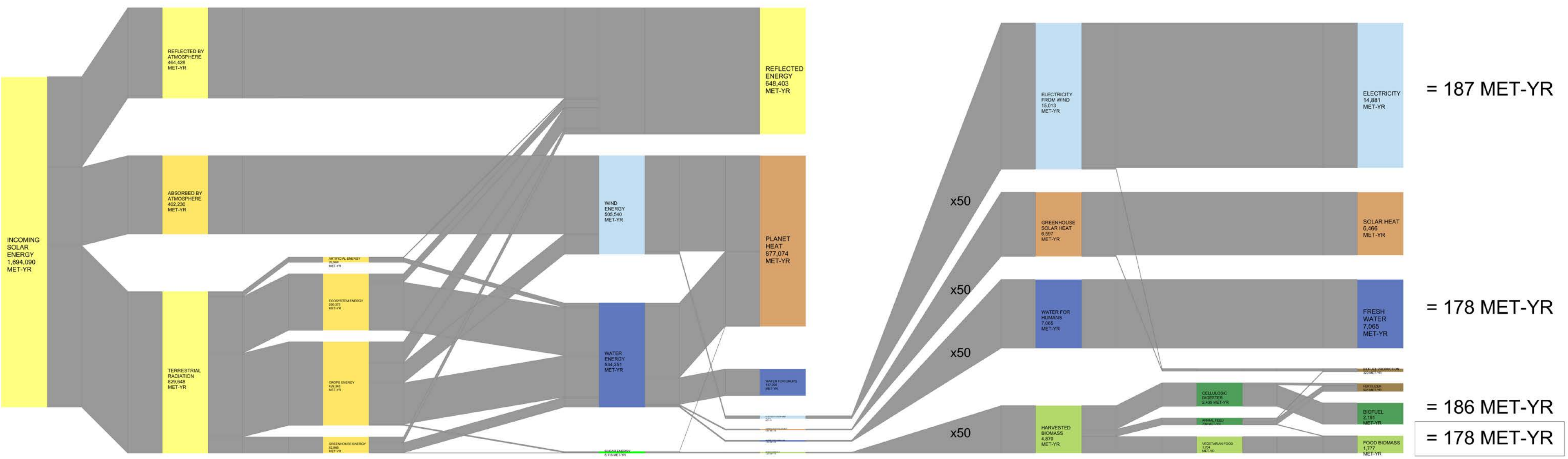
METABOLIC / AMBIENT COMPARISON ENGINE

v0.0.1 by Chris Mackey



LIMITING FACTOR
FOOD + WATER

CAPITAL COST
$7,525,810



178 MAX POP

1 MET = the power used by an average human = 100 Watts
1 MET-DAY = an average human's dietary intake = 2,200 kCal
1 MET-YR = the energy needed to sustain a human for 1 year

Above: The complete report that MAC-E outputs for each land use scenario

integrated solar harvesting for almería, spain

Many experts agree that the most cost-effective means of scaling-up solar power is a concentrated solar thermal strategy that targets the world's desert regions. However, there are several barriers to this approach, notably the requirement for demineralized water to keep mirrors clean and the provision of adequate food and water for workers in extreme desert regions. For this reason, many have suggested a simultaneous deployment of concentrated solar thermal technology with seawater greenhouses, which could address these issues by desalinating large quantities of seawater for drinking purposes, crop irrigation, and mirror cleaning. Additionally, cold sea water that is brought in for desalination can drive the cool end of the steam cycle, enhancing its efficiency while collecting the steam engine's waste heat to produce a more effective desalination of the seawater at a higher temperature. I propose a further innovation on this scheme where the roof of the greenhouse is made of today's standard low-e glass and reflects incoming infrared light not used by the greenhouse plants to a collector that preheats water for the steam cycle. Accordingly, the greenhouse is kept cooler and more amenable to plants by keeping out infrared radiation that would otherwise be converted to heat and the concentrated solar thermal portion of the system becomes more efficient by taking in steam at a higher initial temperature.

Employer - Yale University Center for Earth Observation and MIT Senseable Cities Lab
Duration - 3 years
Date - Spring 2010 - Spring 2013

Concentrated Solar Power

Seawater Desalinating Greenhouses

Reasons for Combining Technologies

1) Extra desalinated water is used to keep mirrors clean and keep system efficiency high.

2) Extra desalinated water acts as the working fluid for the heat collection system since superheated seawater is corrosive.

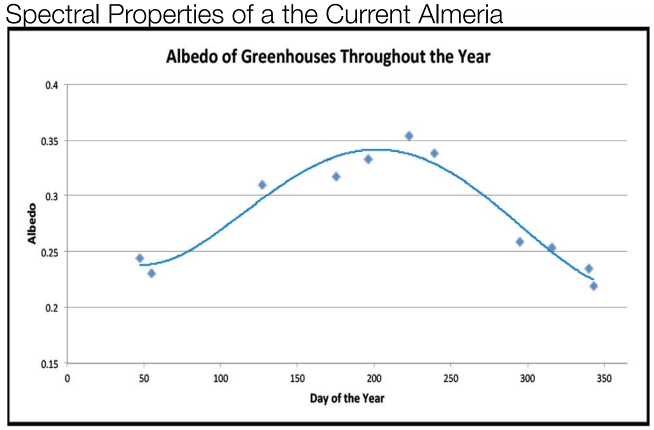
3) Cold seawater brought in for desalination can drive the cold end of steam engines in power plants, keeping steam engine efficiency high.

4) Waste heat transferred to the seawater enables it to be easily desalinated at the hot end of the greenhouse, enabling a greater rate of desalination.

5) Food and fresh water from greenhouses supports local populations running the facility.

Almeria, Spain

Spectral Properties of a the Current Almeria



The greenhouses of Almeria already reflect a lot of solar energy into space in attempts to cool the greenhouse interiors during summer.

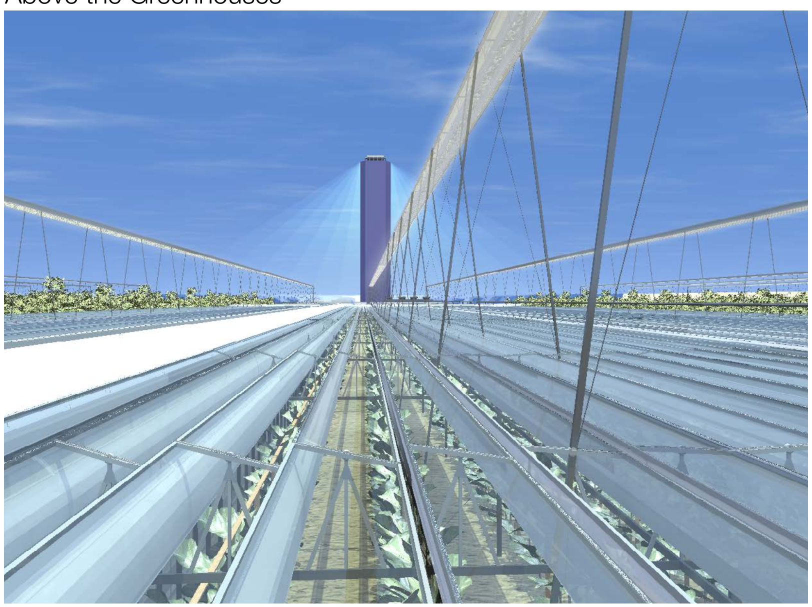
This reflected energy could instead be collected and converted into electricity and distilled water.

By Integrating the Two Systems Using Low-E Glass as the Primary Enclosing and Reflecting Material. We Can:

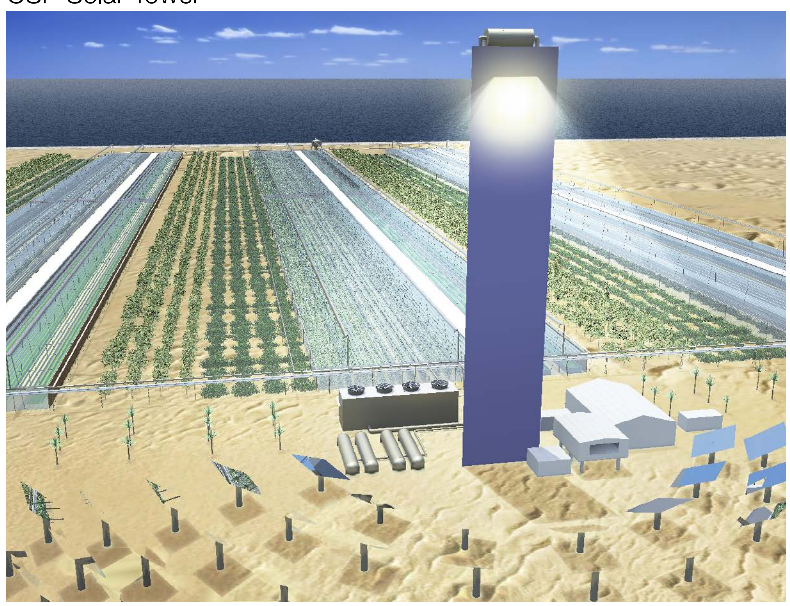
1) Create an even cooler environment inside the greenhouse, enabling deployment in very arid regions.
2) Increase the photosynthetic yield from greenhouse plants by permitting more visible light than a tarp.
3) Help mitigate some of the high cost of solar energy generation with a dual use of heliostats.
4) Maximize overall efficiency of land use, cutting down transportation across the system.

Full Deployable Unit

Above the Greenhouses



CSP Solar Tower

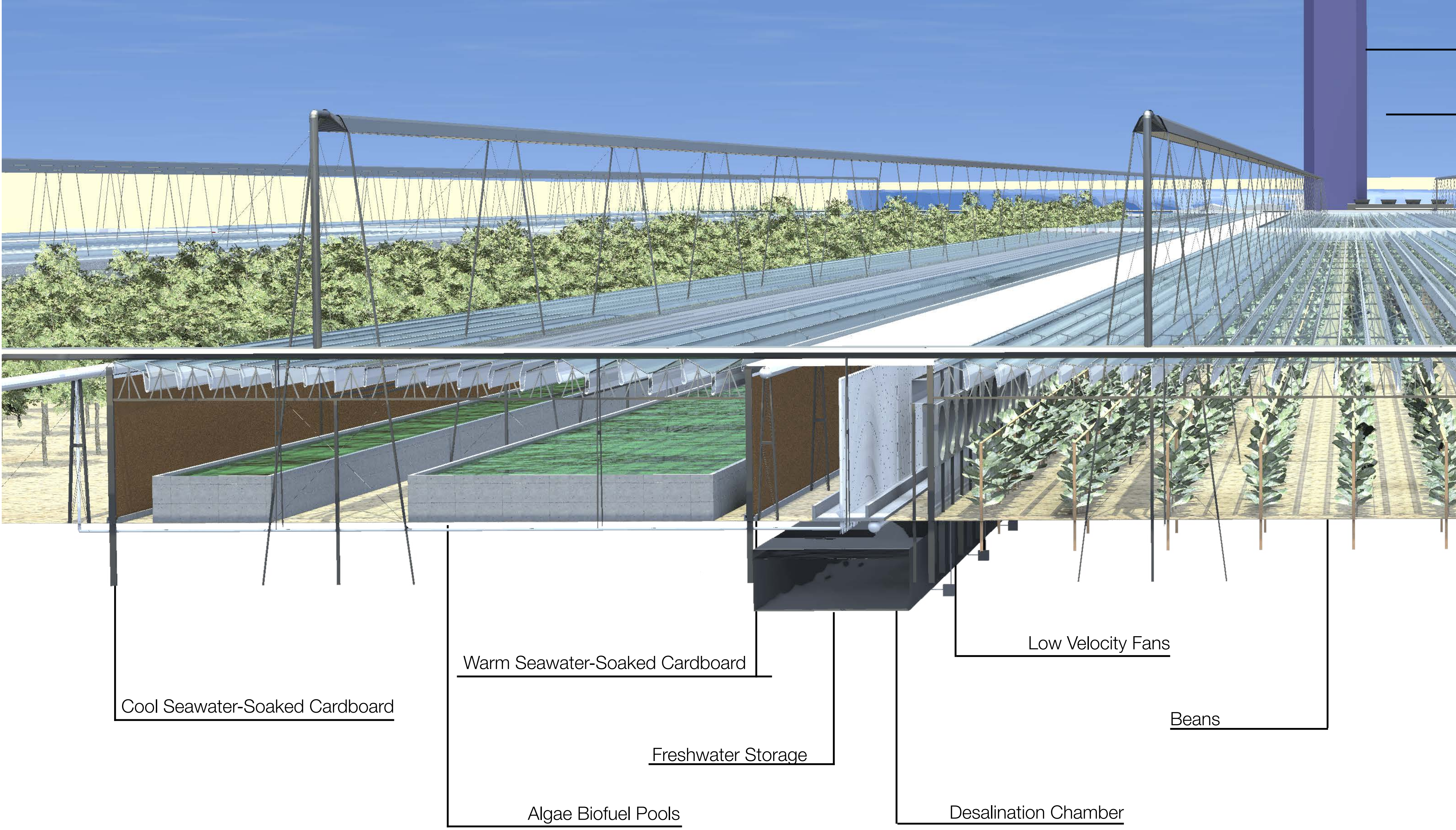


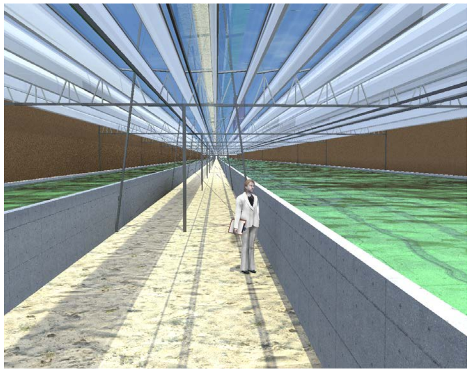
Productive Yield from Deployment Over the Current Almeria:

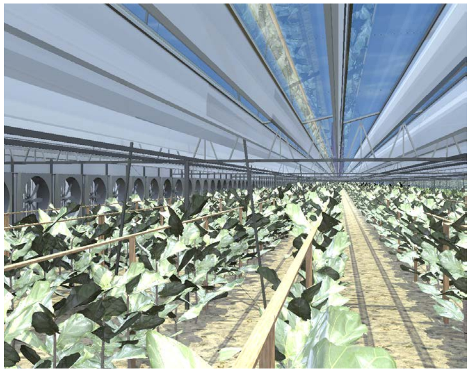
3,447 MW
Electricity
(7 large coal plants)

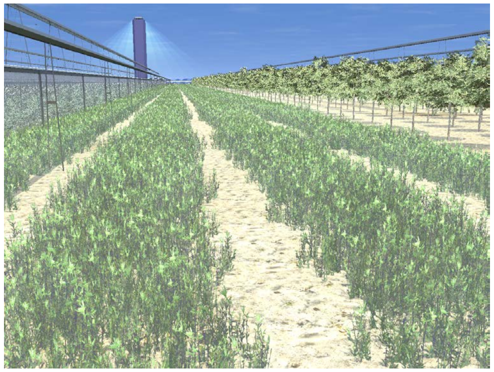
981,119 tones
of Food per Year
(feeds 1.5 million people)

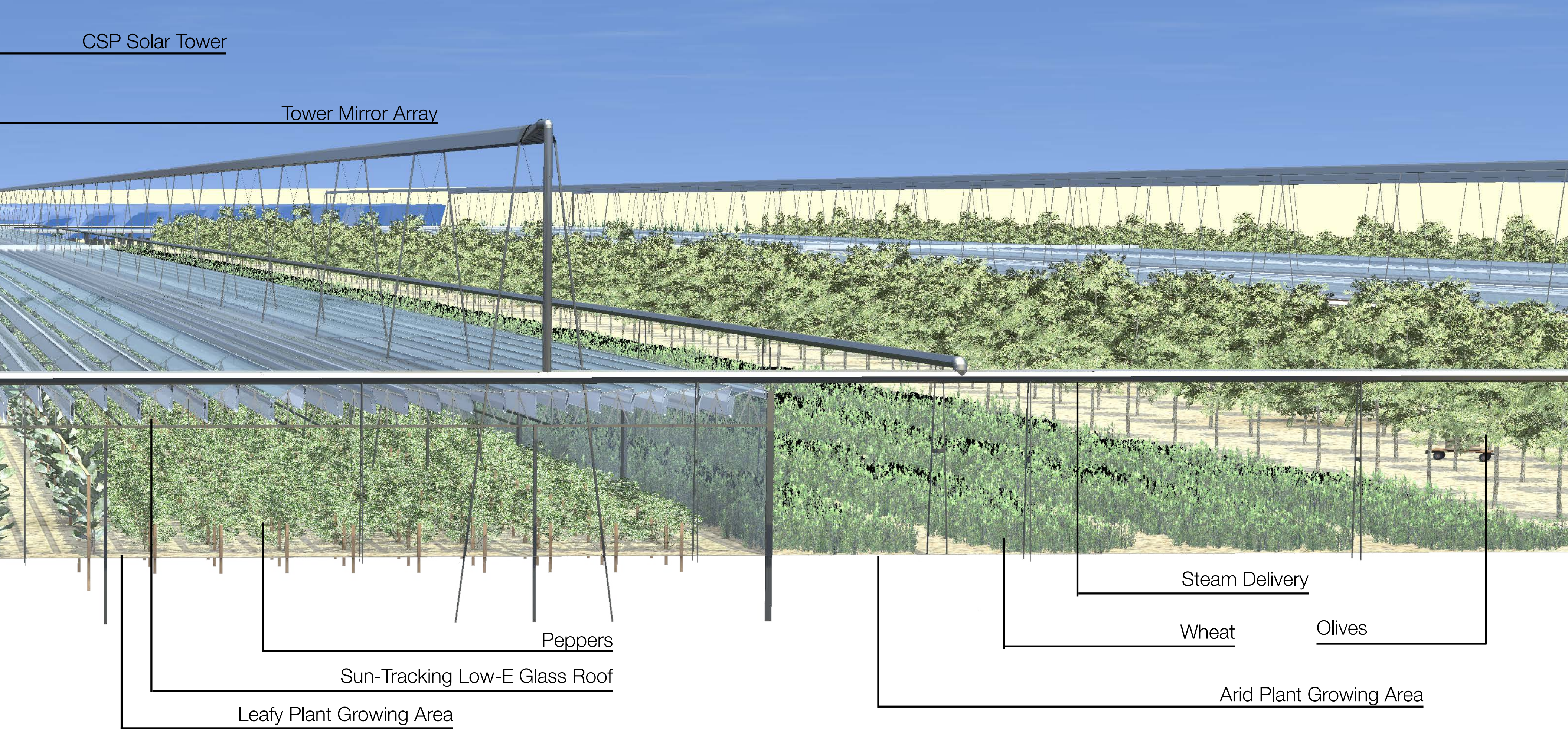
7.1 m^3/s
of Fresh Water
(flow rate of a typical stream)

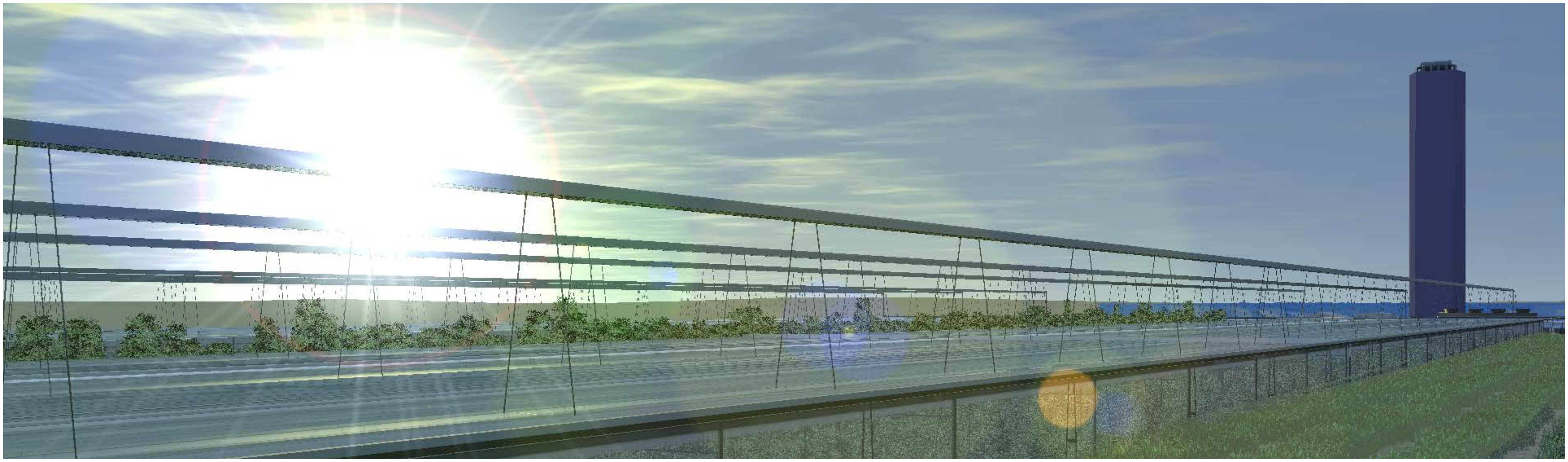

Low Velocity Fans
Warm Seawater-Soaked Cardboard
Cool Seawater-Soaked Cardboard
Beans
Freshwater Storage
Algae Biofuel Pools
Desalination Chamber







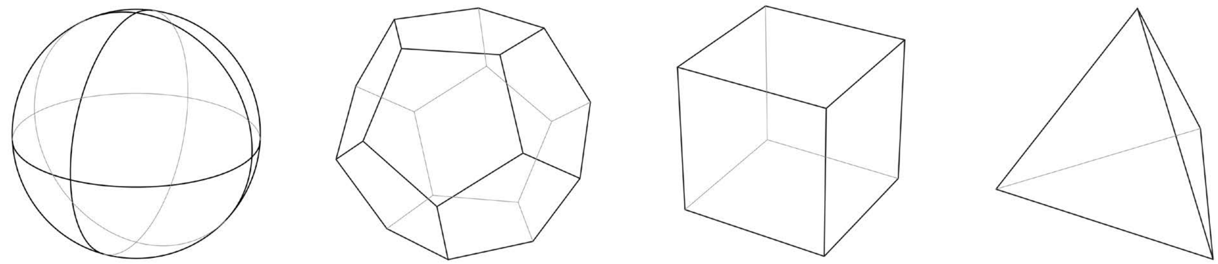

CSP Solar Tower
Tower Mirror Array
Steam Delivery
Wheat
Olives
Peppers
Sun-Tracking Low-E Glass Roof
Arid Plant Growing Area
Leafy Plant Growing Area



fractal min/max surface area object

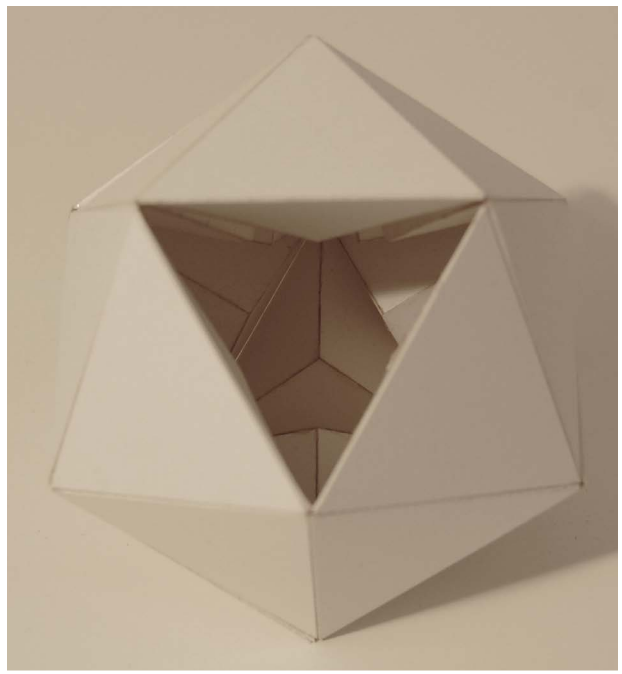
The modern building envelope has often attempted to minimize unwanted losses or gains to the environment through minimization of exterior surface area. However, it is important to remember that there are also many cases in which a high surface area is desired, such the crenelated nature of radiators and coils that help exchange heat efficiently with the interior environment, reducing the hotness or coldness of supply air or water.

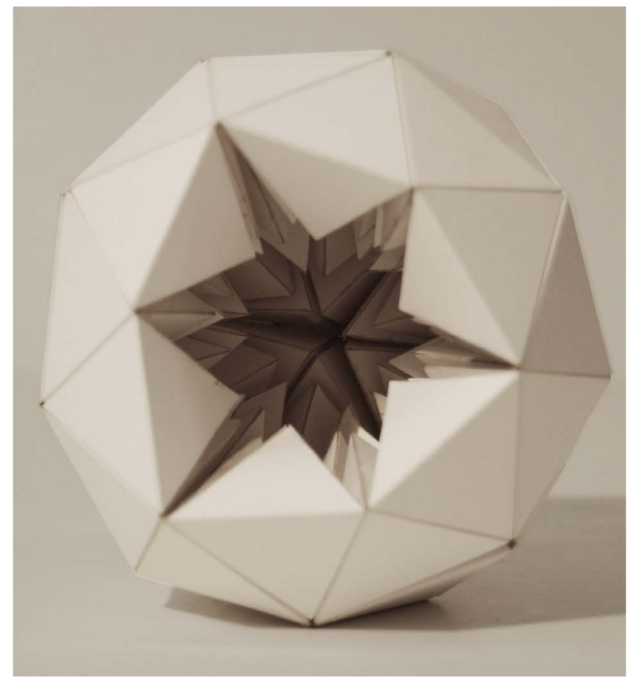
The following project explores potential new geometries resulting from this min/max surface area dichotomy.

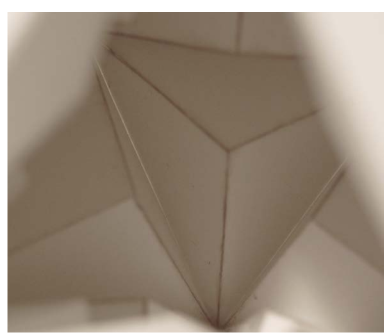


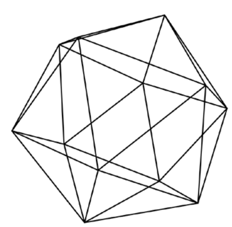
The process begin by identifying the 3-D geometries with the greatest and smallest surface area to volume ratios: the tetrahedron and the sphere respectively.

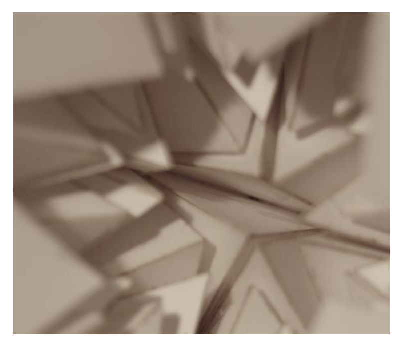
The combination of the sphere and the tetrahedron that produced the greatest contrast in interior and exterior surface area is an icosahedron where each of the outside triangles extends inward as a tetrahedron.

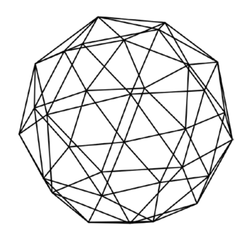




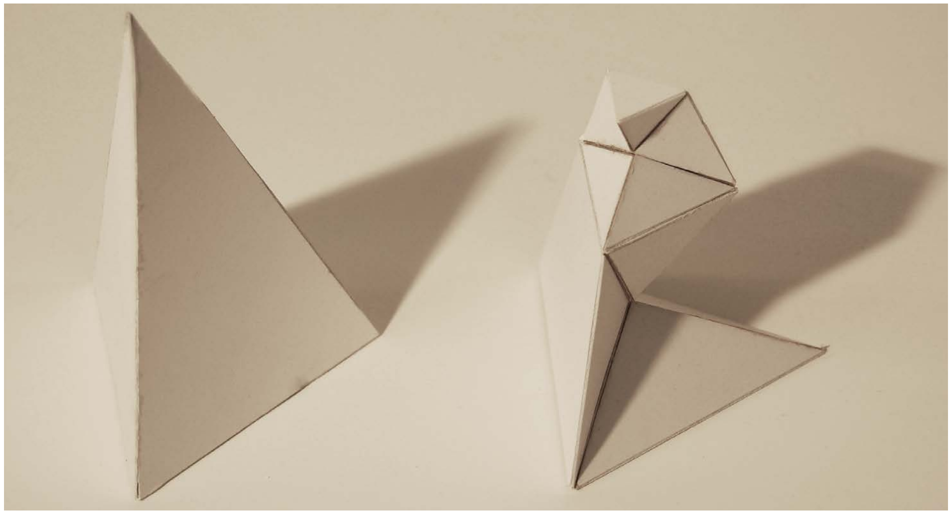


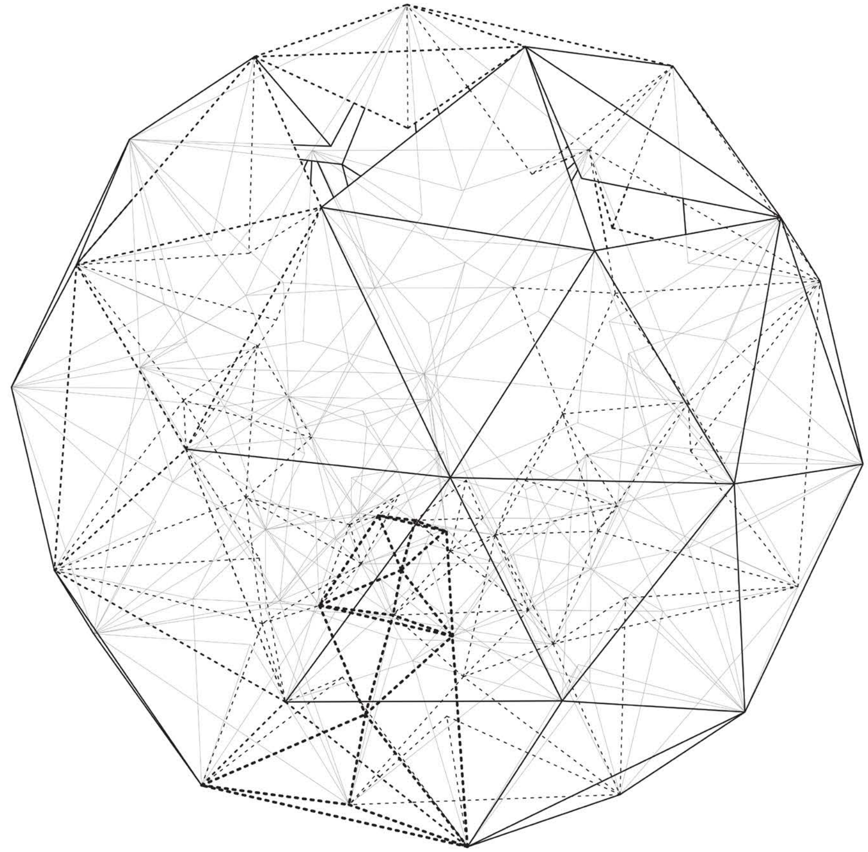






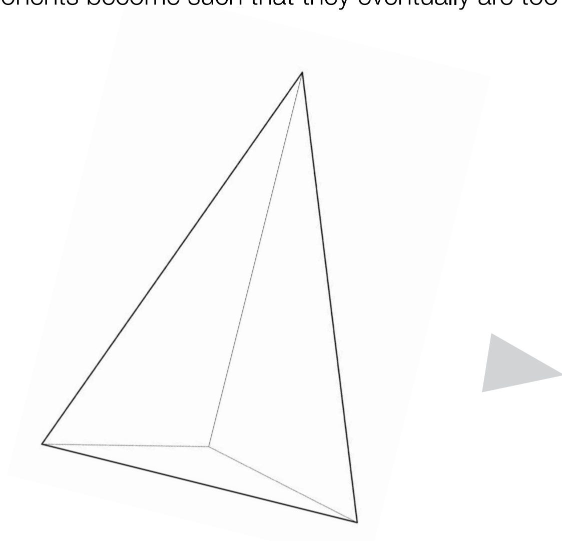
Project Type - Academic
Role - Designer (the only one)
Duration - 4 Weeks
Date - Fall 2011

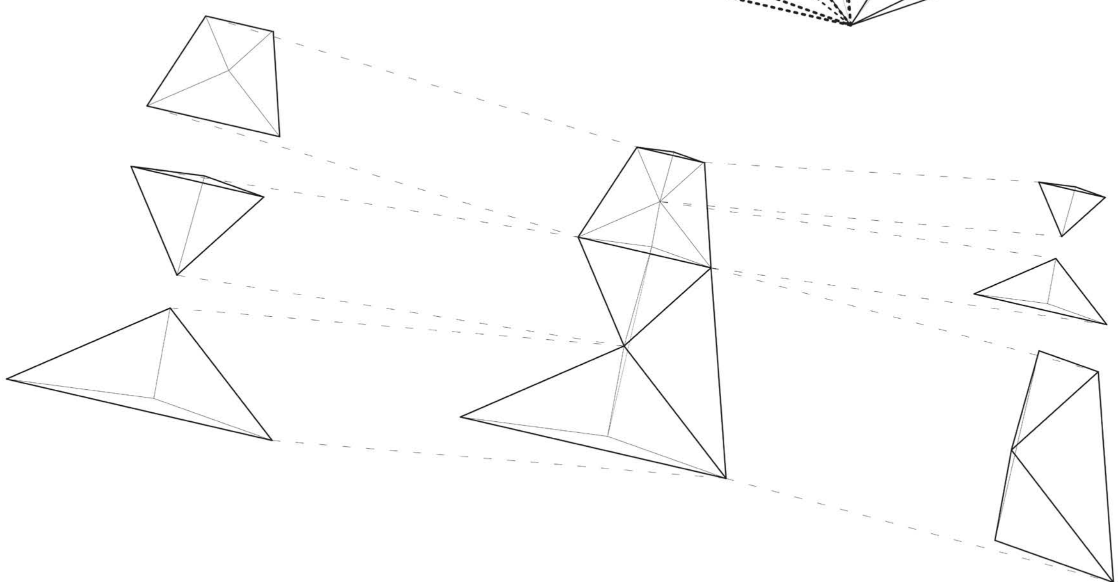




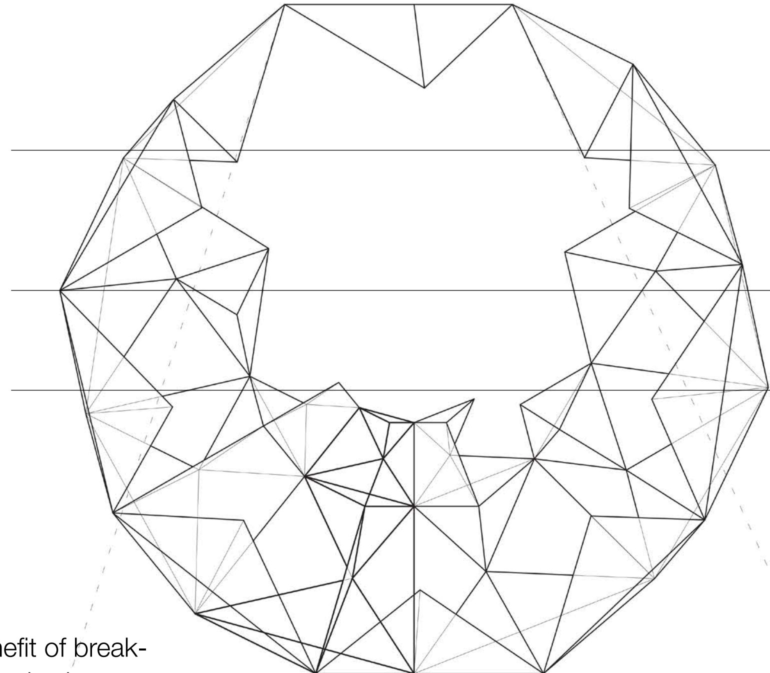
Upon realizing the potential to iterate the scheme on the previous page to infinity, one pathway to the object with the greatest possible interior surface area and smallest possible exterior surface area is understood.

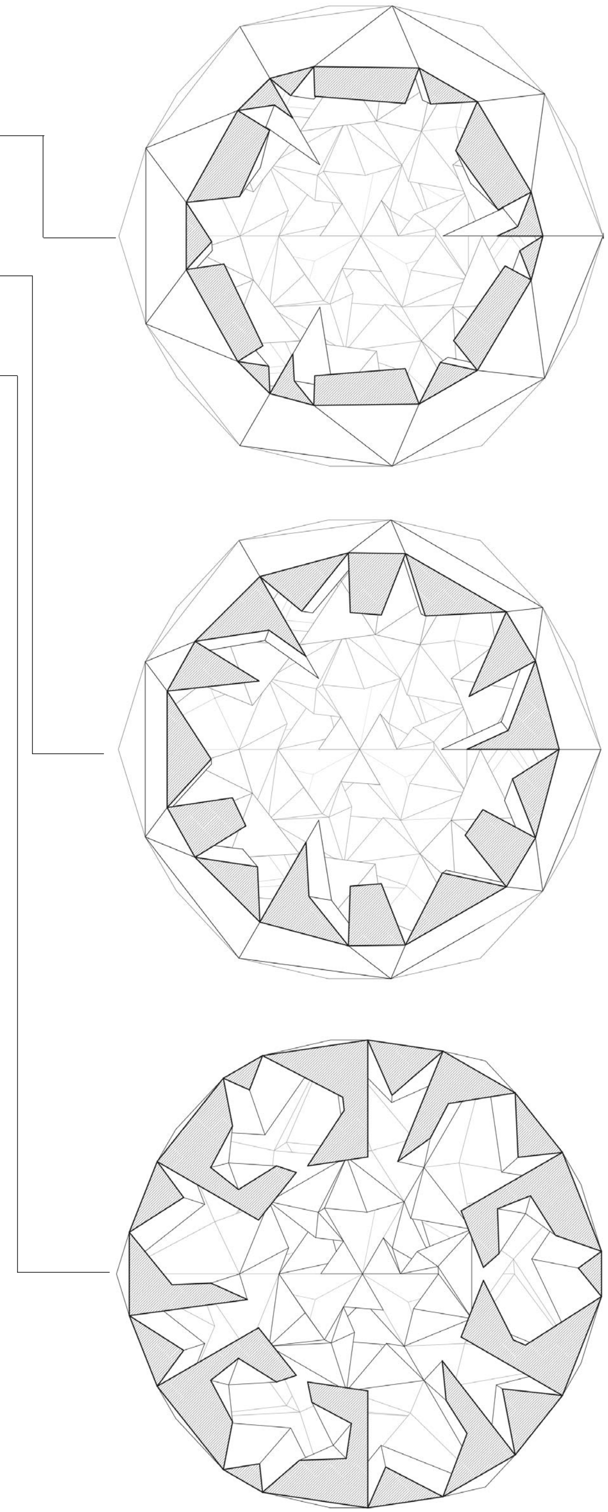
However, in the attempt to physically create further iterations along this pathway, a new problem arises: as more iterations are done, the thinner the tetrahedral components become such that they eventually are too thin and frail for assembly.



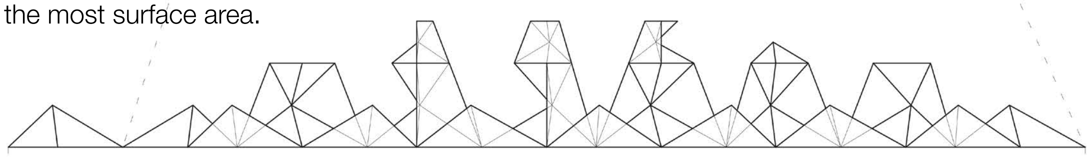


To address this issue, a new scheme for breaking down the tetrahedrons is developed. This involves the division of the tetrahedrons within the sphere into smaller pyramids laterally along their length.

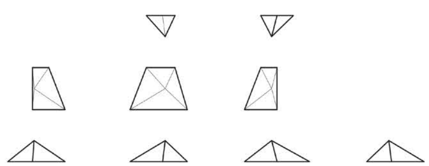


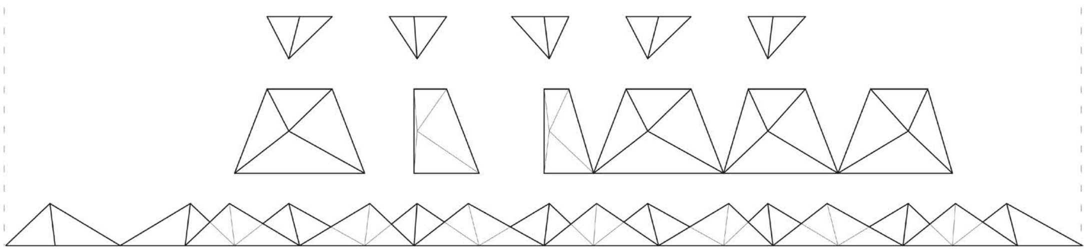


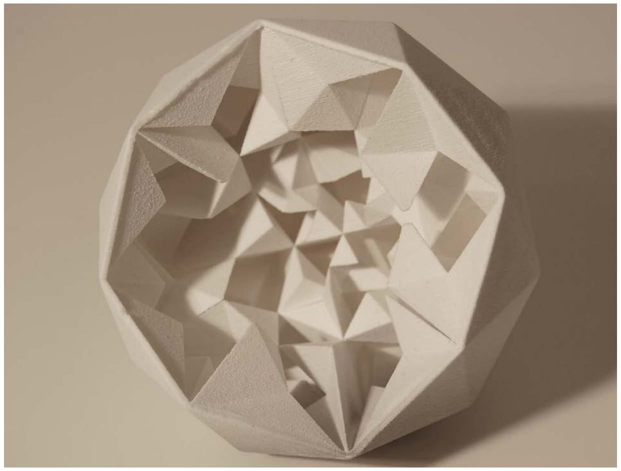
Another benefit of breaking down tetrahedrons in this manner is that it allows for localized control over which regions have the most surface area.

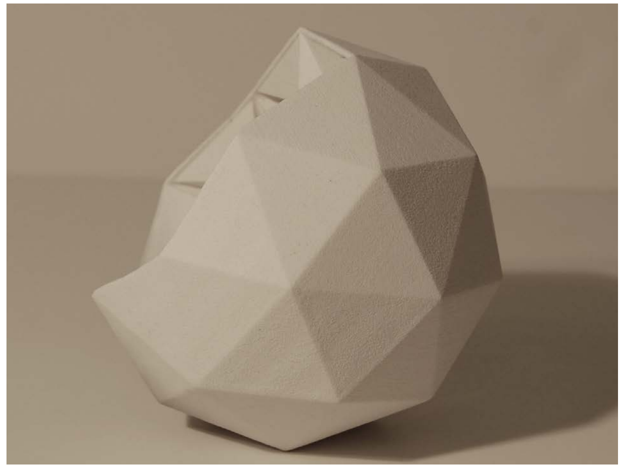


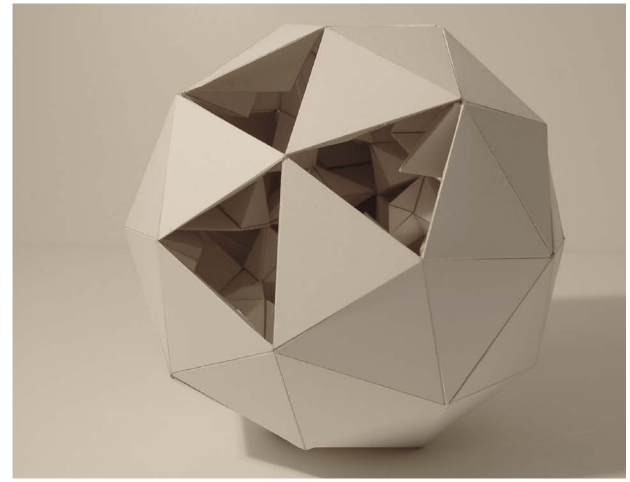
Sections from bottom to top show how the complexity of the wall increases as one moves towards the bottom of the sphere.

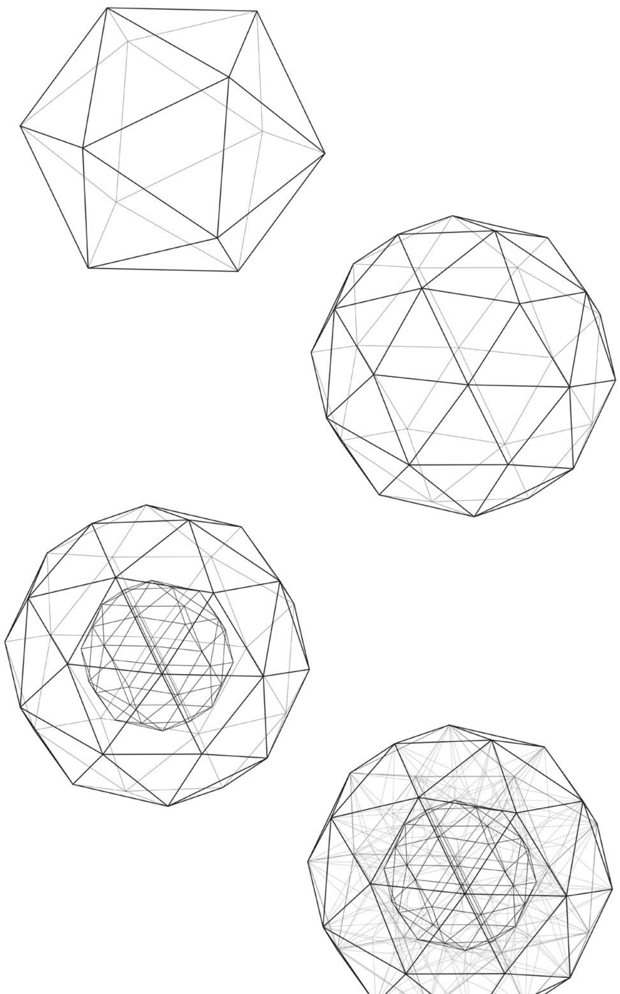


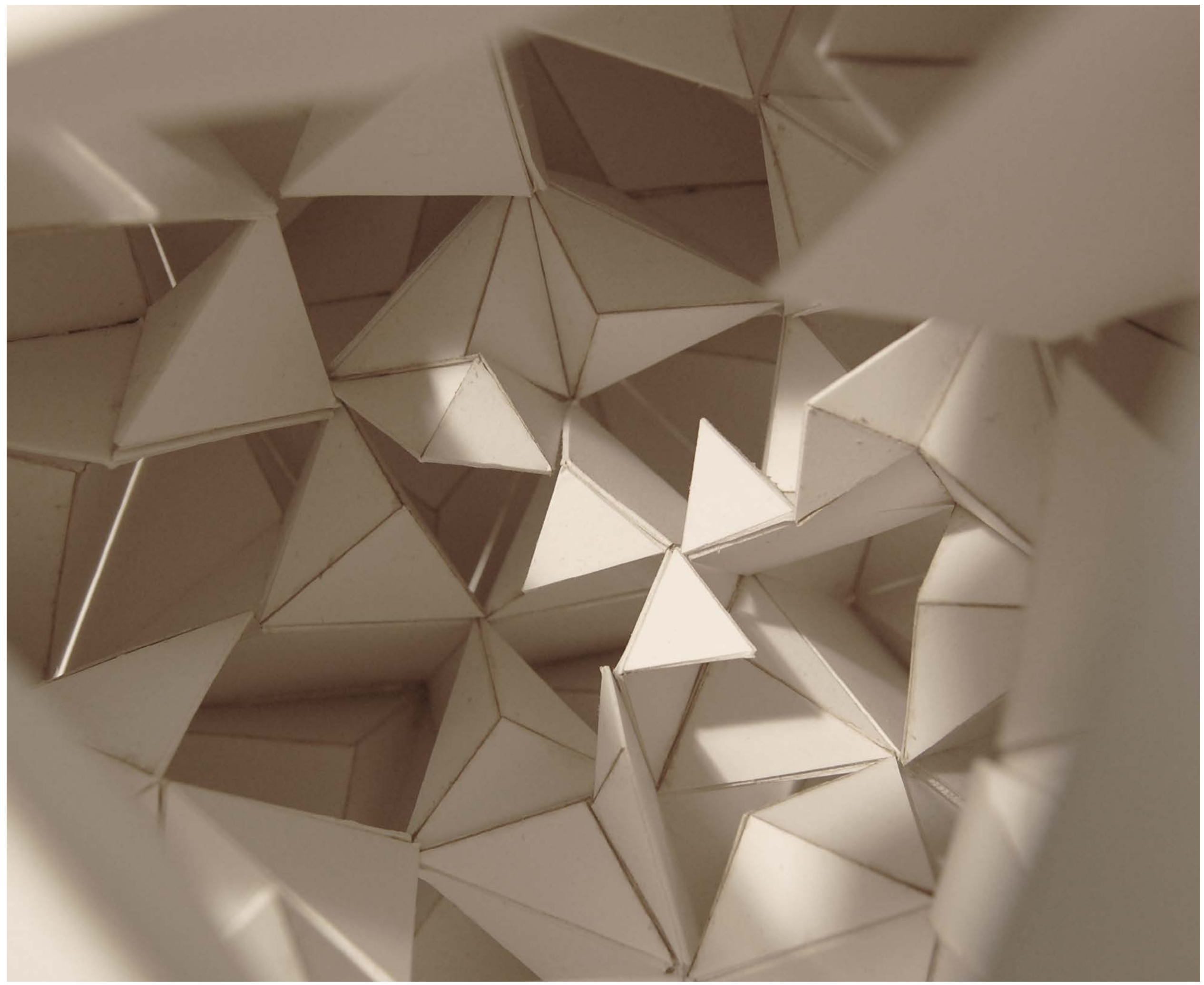


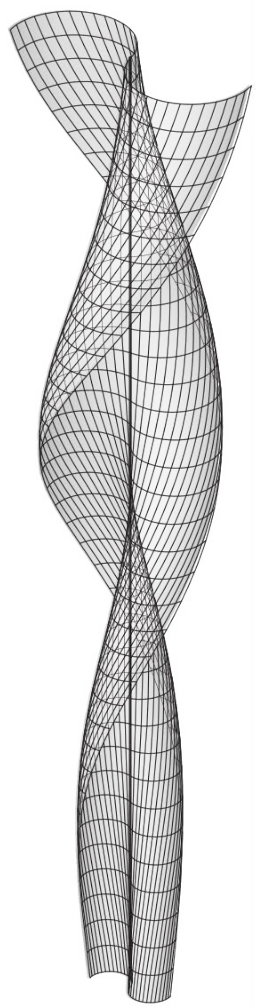












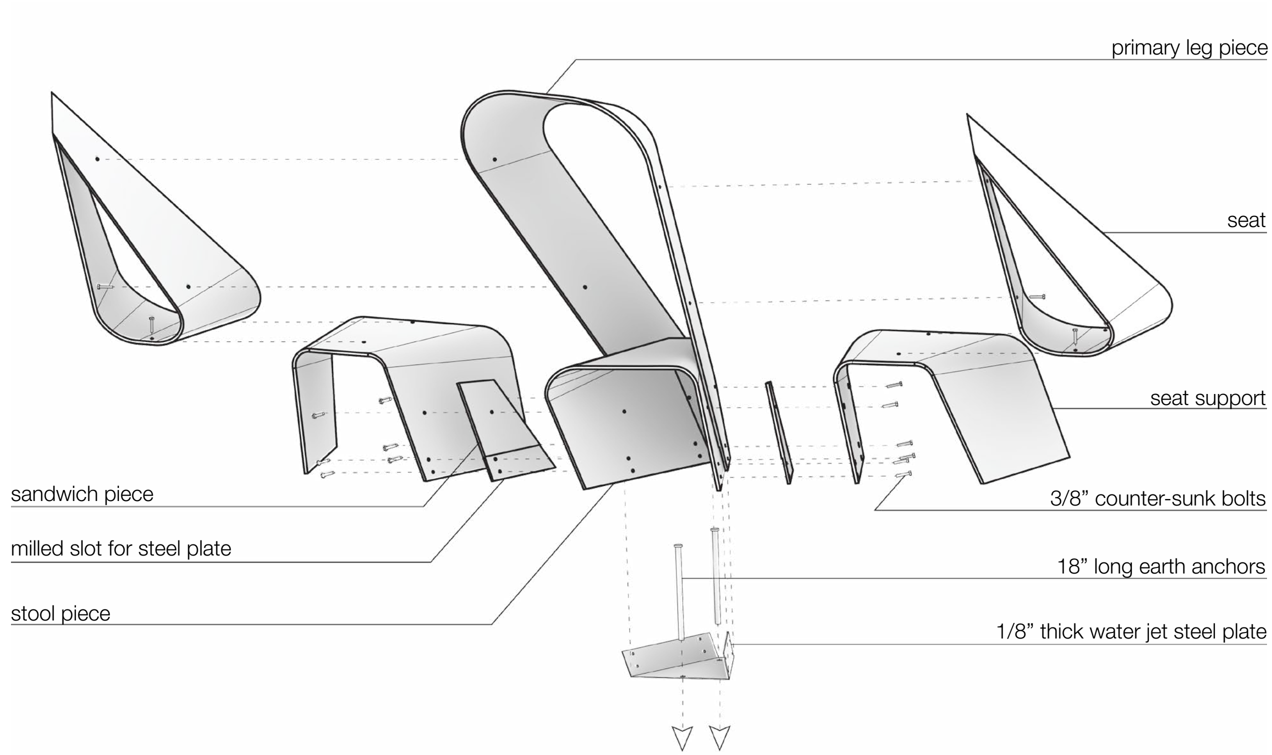
fabrication experiments

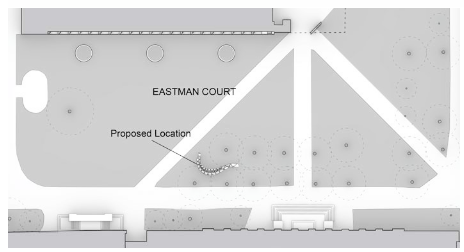
digital fabrication experiment

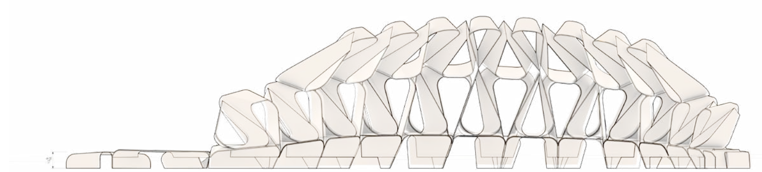
After proposing a number parametric designs that would require digital fabrication in order to be physically realized, I and two other classmates wrestled with the digital fabrication process to produce a pavilion.

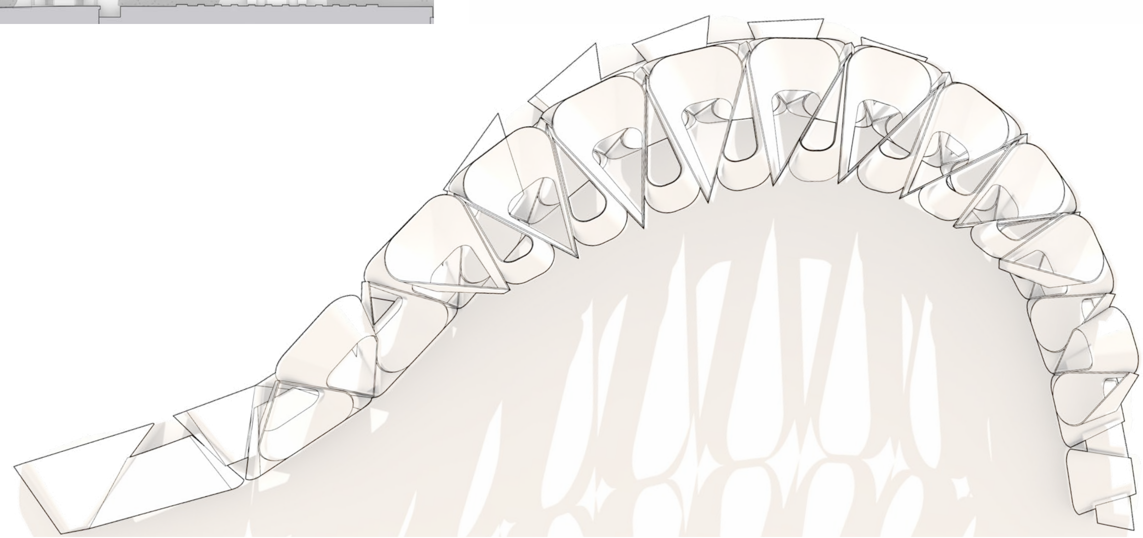
The design of the pavilion is the result of an old technique that is reinvented using digital strategies and tools. Kerfing, the cutting of wood to add flexibility, has a long history in wood working. Our research combined the material logic of kerfing with the flexibility of parametric modeling and the accuracy of a CNC router. Our parametric model integrated all the digital steps in the modeling and fabrication process, from initial control over the global form to the unrolling and generation of the cut patterns required to make each unit. The patterns allow plywood to bend into predictable shapes without additional tools or techniques.

Project Type - Academic
Role - Designer and Fabricator (one of 3)
Duration - 7 Months
Date - Spring 2012







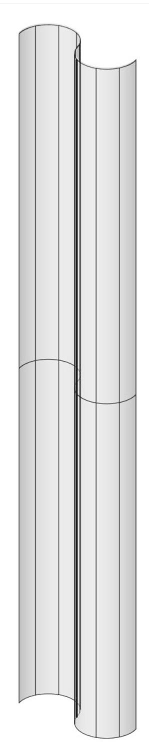




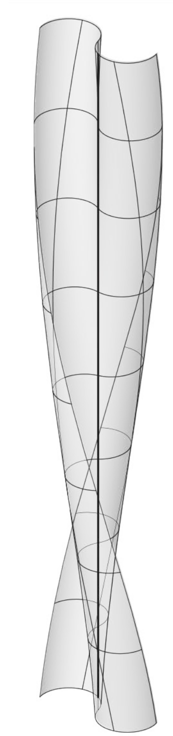


building airflow installation

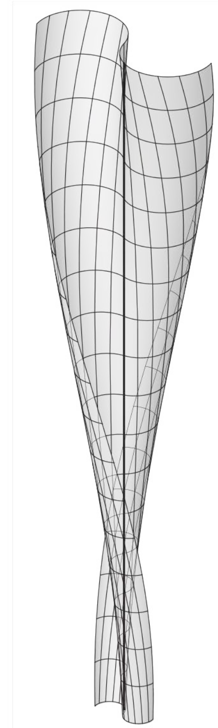
Throughout the interconnected superbuilding that houses MIT's central campus, dynamic patterns of air currents fluctuate in response to outdoor temperature, wind, building mechanical systems, elevator use, vacuums pumps in machine shops and the simple opening and closing of doors over the building's vast internal expanse. While these currents are always changing and echoing throughout the superbuilding's enclosure, such movement is often invisible and building users often rely on other senses to evaluate it. This installation aims to render such invisible movement visible and ultimately engender a new level of awareness and interactivity with the building's air movement.



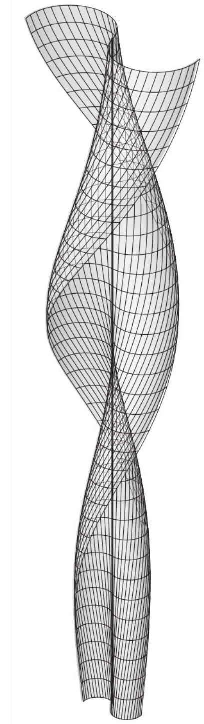
1. Initially, we take the form of a vertical-axis turbine with airfoil-shaped fins so that the turbine will turn in only one direction in response to wind.



2. To get a turbine with only 2 fins to work (as opposed to an original 4 fin one), we twist the turbine so that it will respond to wind from any direction.

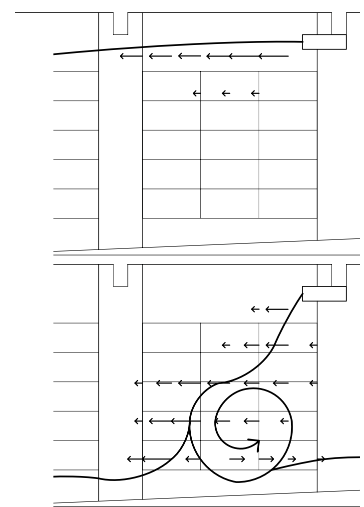


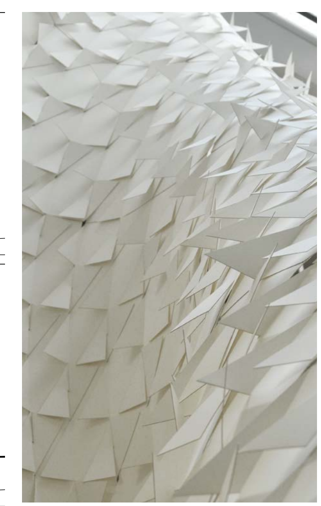
3. The turbine is tapered from such that it will turn at a different rate in response to cool (bottom) versus warm (top) air coming out of a nearby vent.

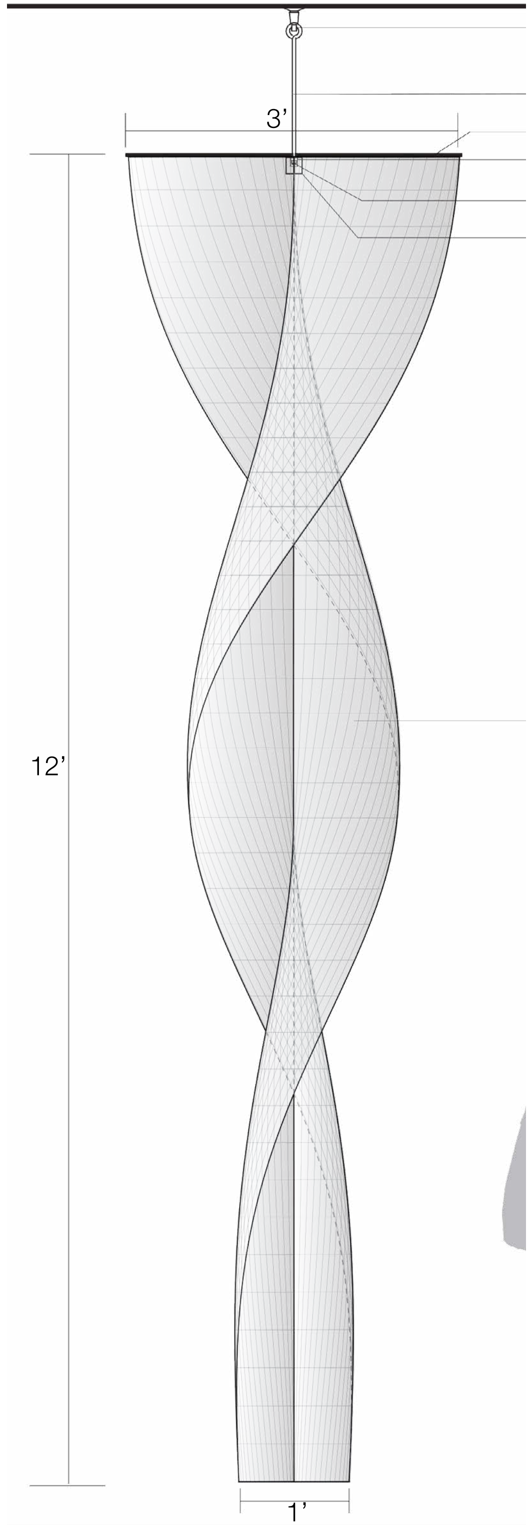


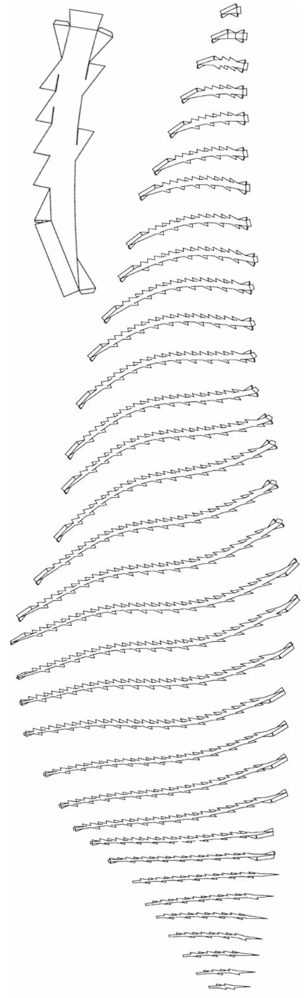
4. The final form includes two more twists so that the various paper components will hold the desired global shape.

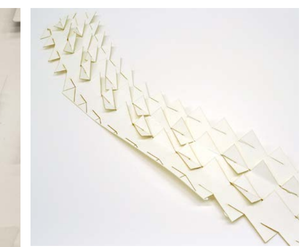
Project Type - Academic
Role - Designer (one of 3 total)
Duration - 4 Weeks
Date - Fall 2011

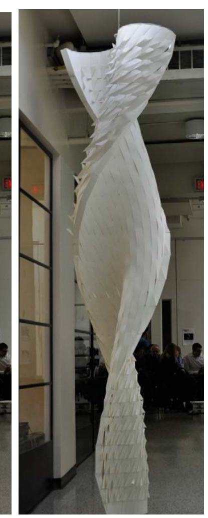


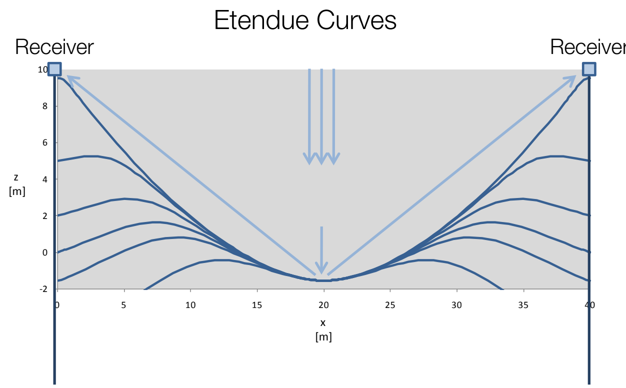


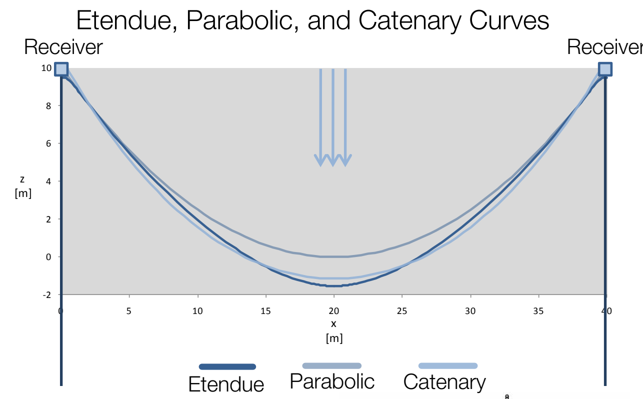

3’
12’
1’







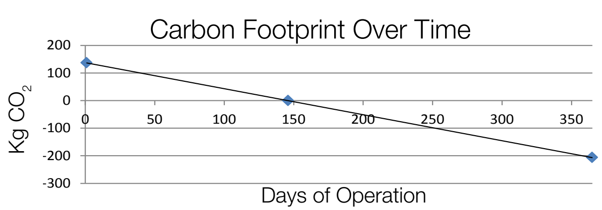


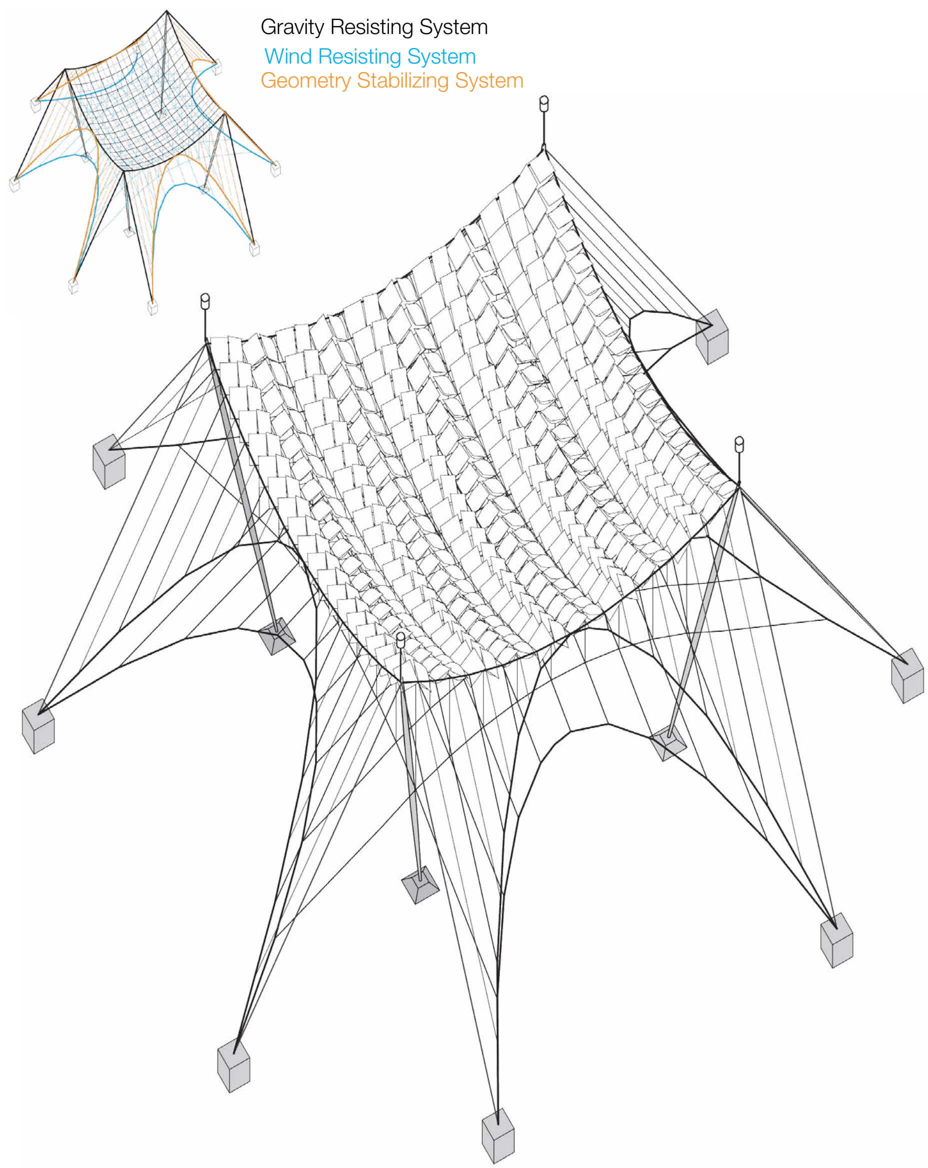


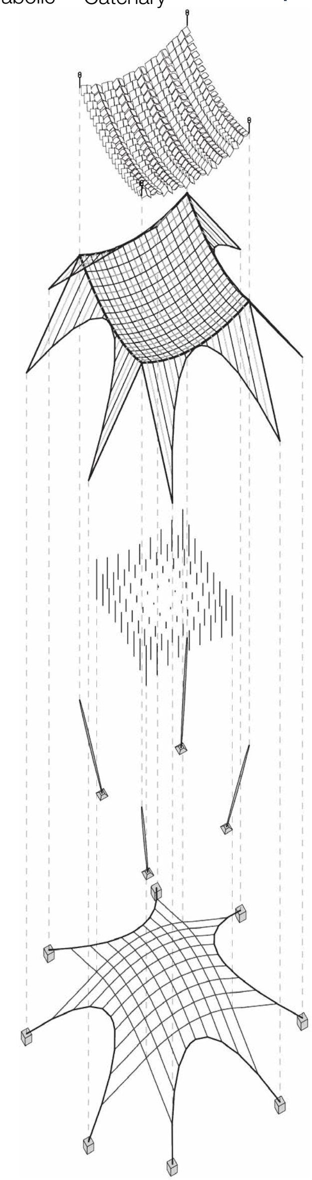
parametric canopy for concentrated solar collection

When designing concentrated solar collectors, optical engineers will often arrange mirrors in a manner such that they cast the least amount of shadow on each other. Such an arrangement is called an etendue curve and typically looks like the following:

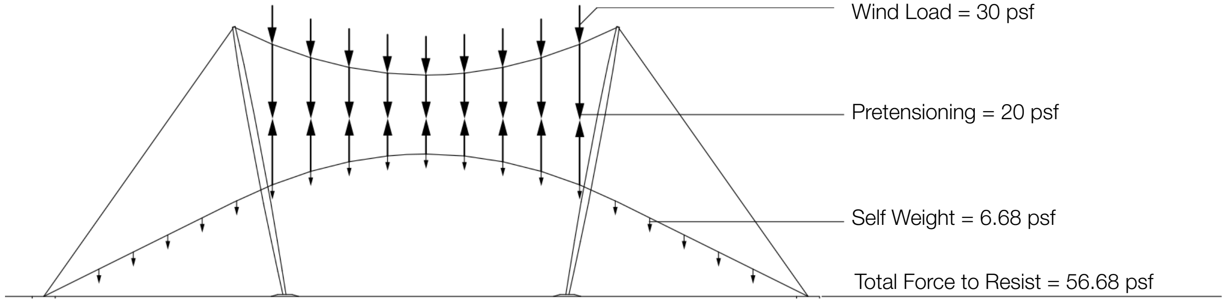
This project began with the realization that one etendue curve is similar in form to the catenary, which has often been critical to making many of today's most structurally efficient buildings and tensile canopies. The following design emerged after several studies into how structurally and optically efficient such a canopy could be. From the forces in the members, the study derived the amount of material required, the embodied CO_2 of such material, and the eventual CO_2 and cost payback periods.

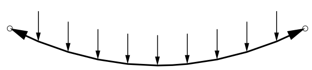




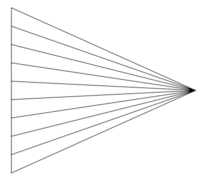


Project Type - Academic
Role - Designer and Structural Engineer
Duration - 7 months
Date - Winter-Summer 2012

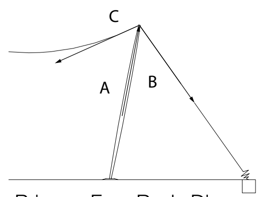




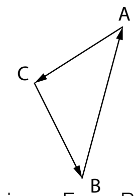
Secondary Free Body Diagram



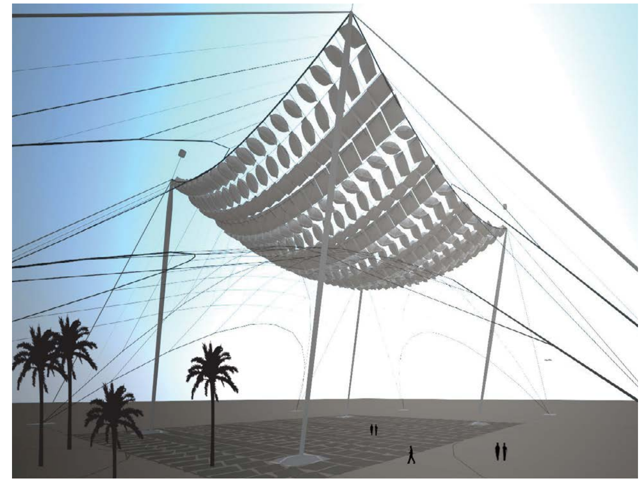
Secondary Force Polygon

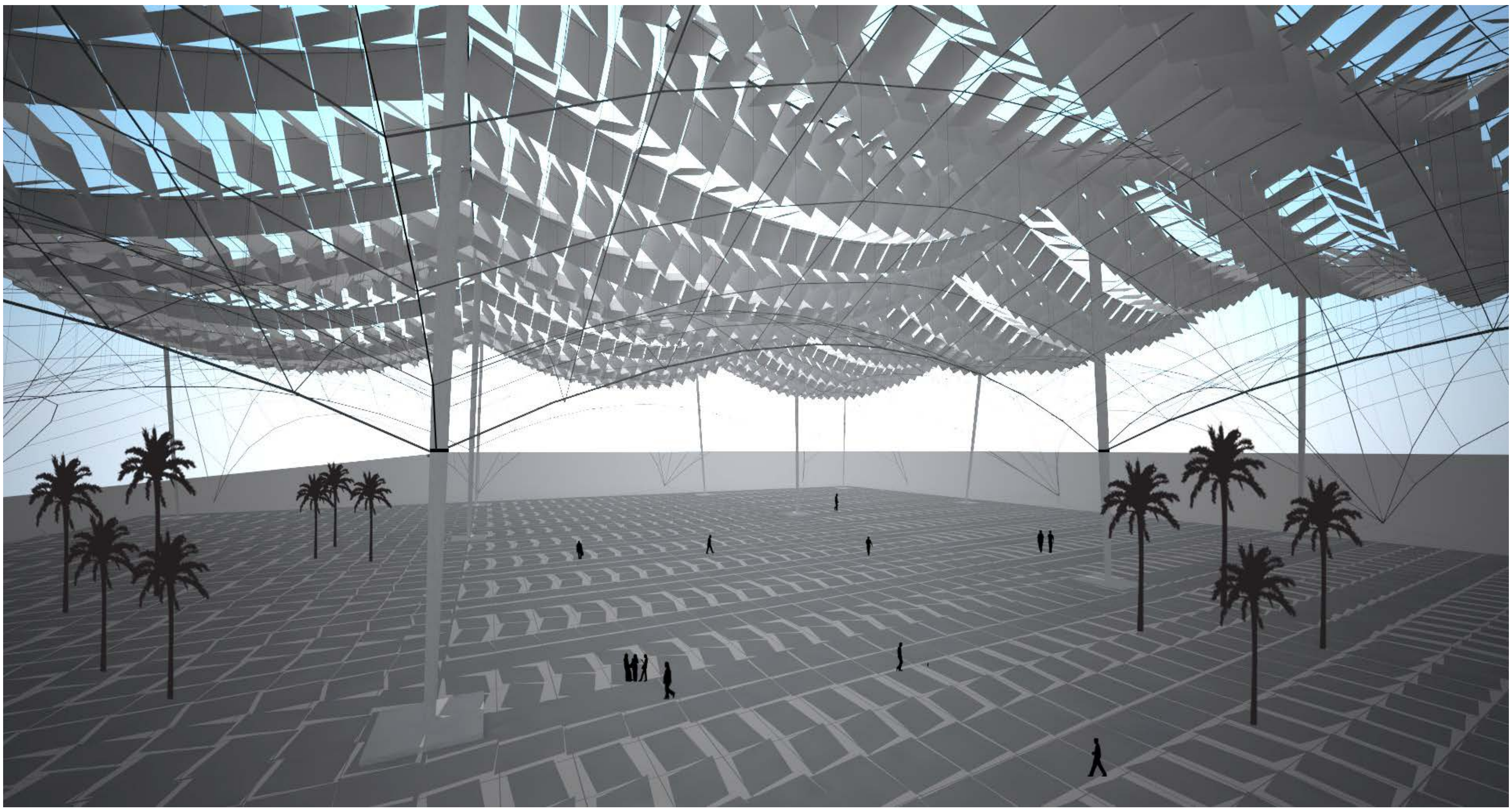


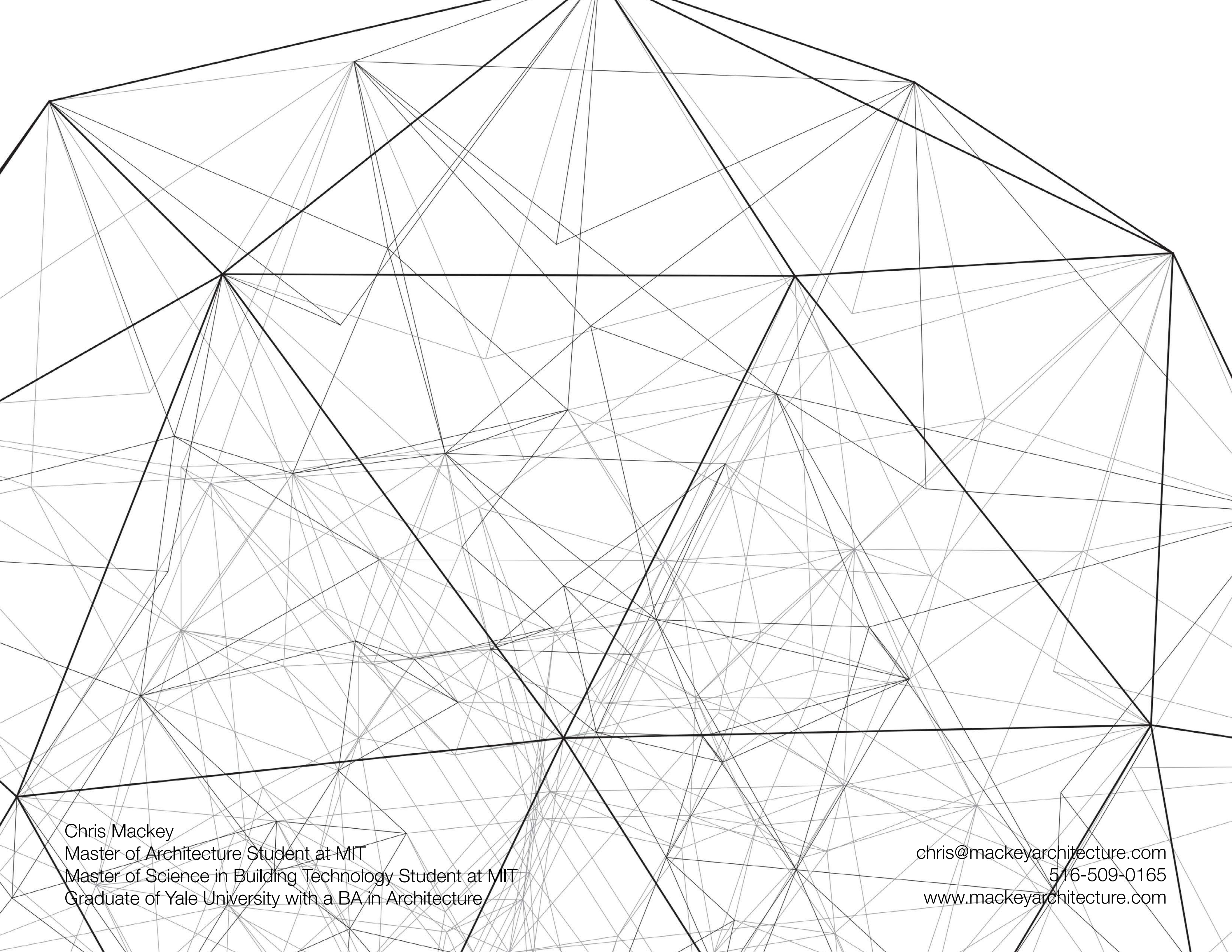
Primary Free Body Diagram



Primary Force Polygon







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