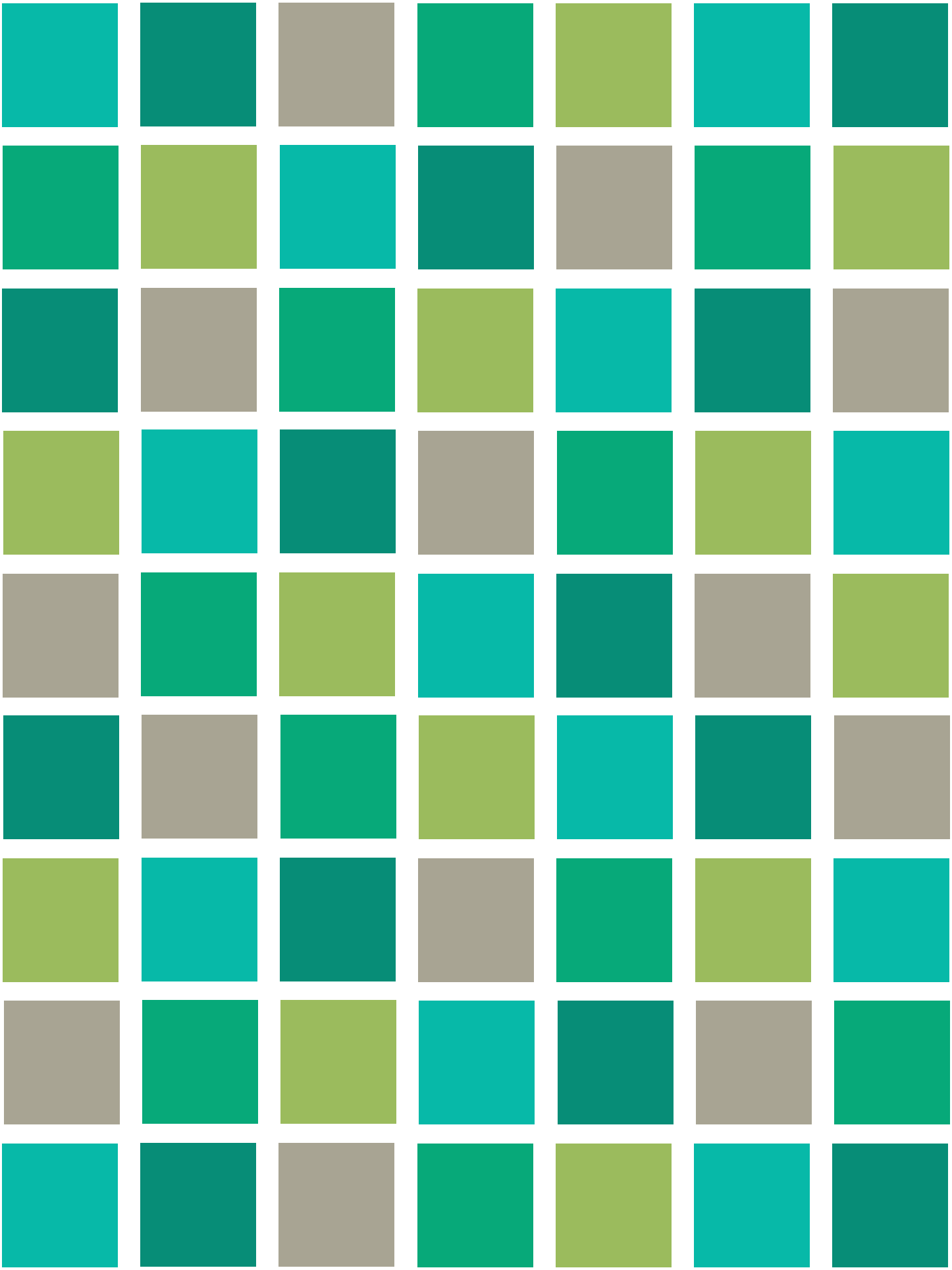
adaptable architecture

architecture that changes through time

k.hughes



adaptable architecture

architecture that changes through time.

A Design Thesis Submitted to the Department of Architecture and Landscape Architecture of North Dakota State University

by

KATHRYN E.HUGHES

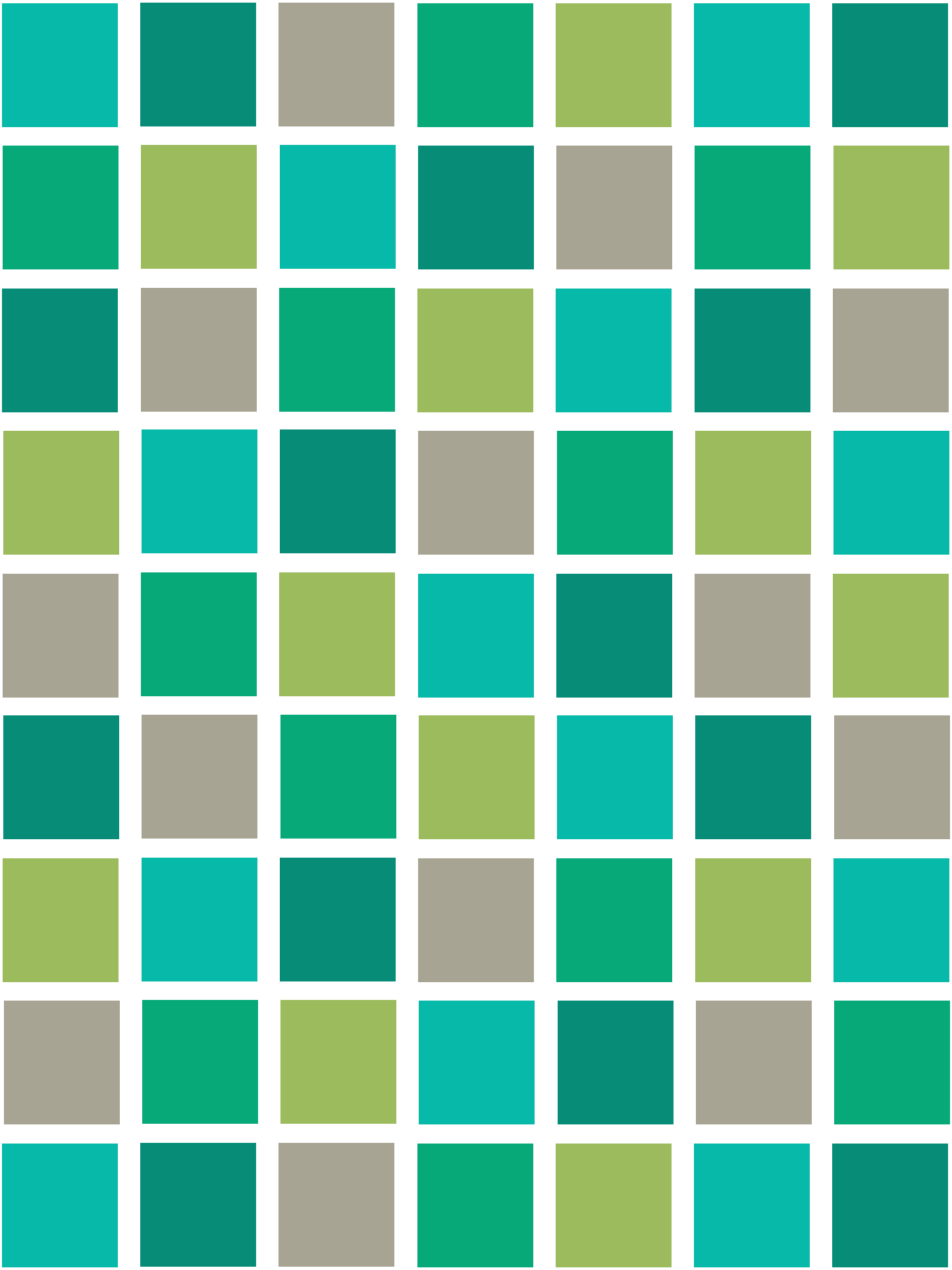
In Partial Fulfillment of the Requirements for the Degree of Master of Architecture

Primary Thesis Advisor

05/12/11

Thesis Committee Chair

May 2011
Fargo, North Dakota



distribution license

By signing and submitting this license, I (Kathryn Hughes) grant to North Dakota State University (NDSU) the non-exclusive right to reproduce, translate (as defined below), and/or distribute my submission (including the abstract) worldwide in print and electronic format, as well as in any medium, including but not limited to audio or video.

I agree that NDSU may, without changing the content, translate the submission to any medium or format for the purpose of preservation.

I also agree that NDSU may keep more than one copy of this submission for purposes of security, back-up and preservation.

I represent that the submission is my original work, and that I have the right to grant the rights contained in this license. I also represent that my submission does not, to the best of my knowledge, infringe upon anyone's copyright.

If the submission contains material for which I do not hold copyright, I represent that I have obtained the unrestricted permission of the copyright owner to grant NDSU the rights required by this license, and that such third-party owned material is clearly identified and acknowledged within the text or content of the submission.

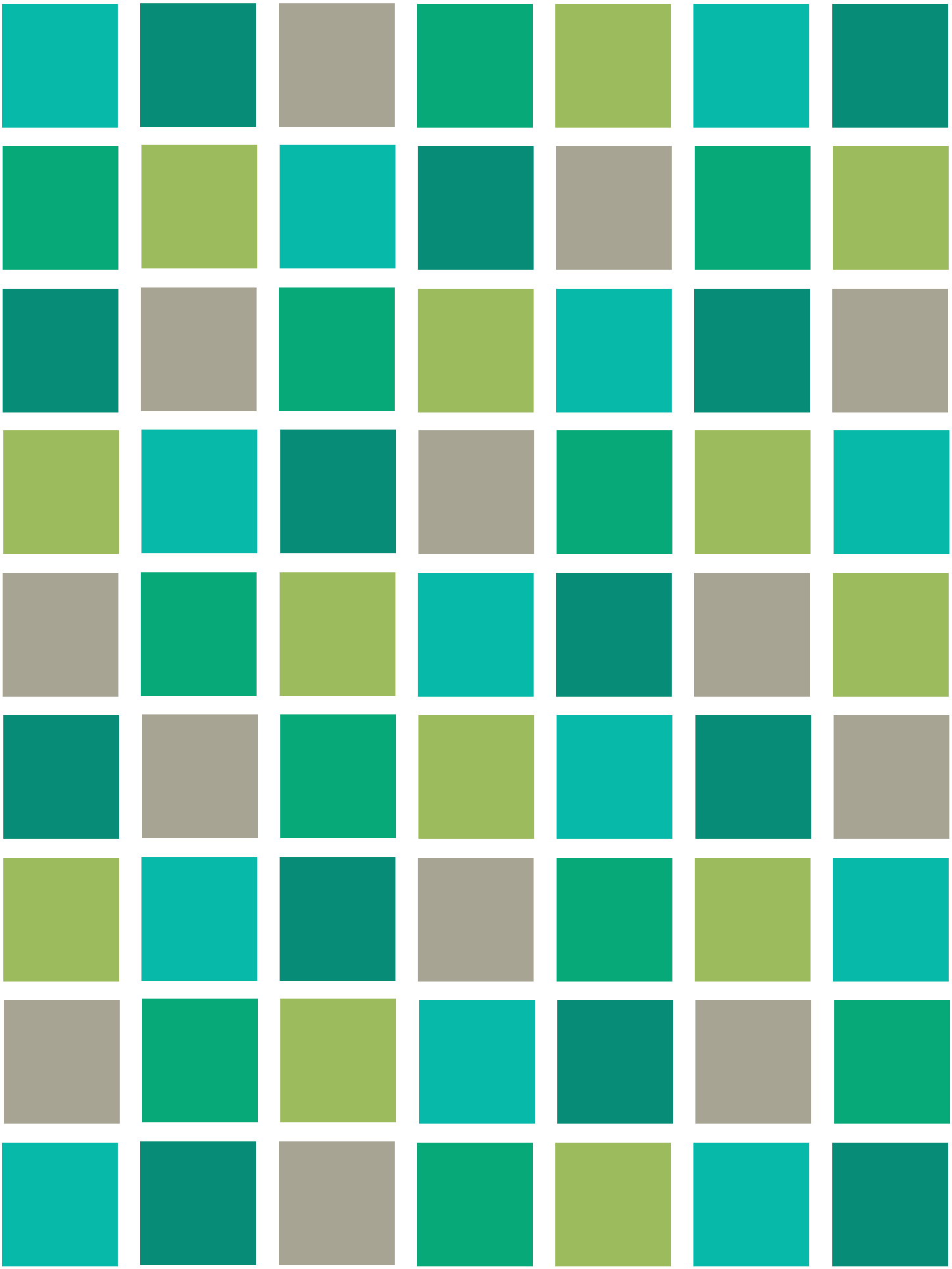
IF THE SUBMISSION IS BASED UPON WORK THAT HAS BEEN SPONSORED OR SUPPORTED BY AN AGENCY OR ORGANIZATION OTHER THAN NDSU, I REPRESENT THAT I HAVE FUFILLED ANY RIGHT OF REVIEW OR OTHER OBLIGATIONS REQUIRED BY SUCH CONTRACT OR AGREEMENT.

NDSU will clearly identify my name(s) as the author(s) or owner(s) of the submission, and will not make any alteration, other than as allowed by this license, to my submission.

05.12.11

Student Signature Date

table of contents



adaptable architecture

a thesis

abstract

Just as living things grow and adapt, so should the things we create. In this juxtaposition lays the ability to propel our creations into a cyclical lifestyle of rebirth through functionality. Spatial experiences are received directly as an extension of one's body, as a dynamic recipient from a static host. In this perspective, it is possible for a dynamic relationship between an individual & their built environment to exist. A building should be able to grow and adjust as we do, creating the opportunity for regeneration & recycling of function & materiality.

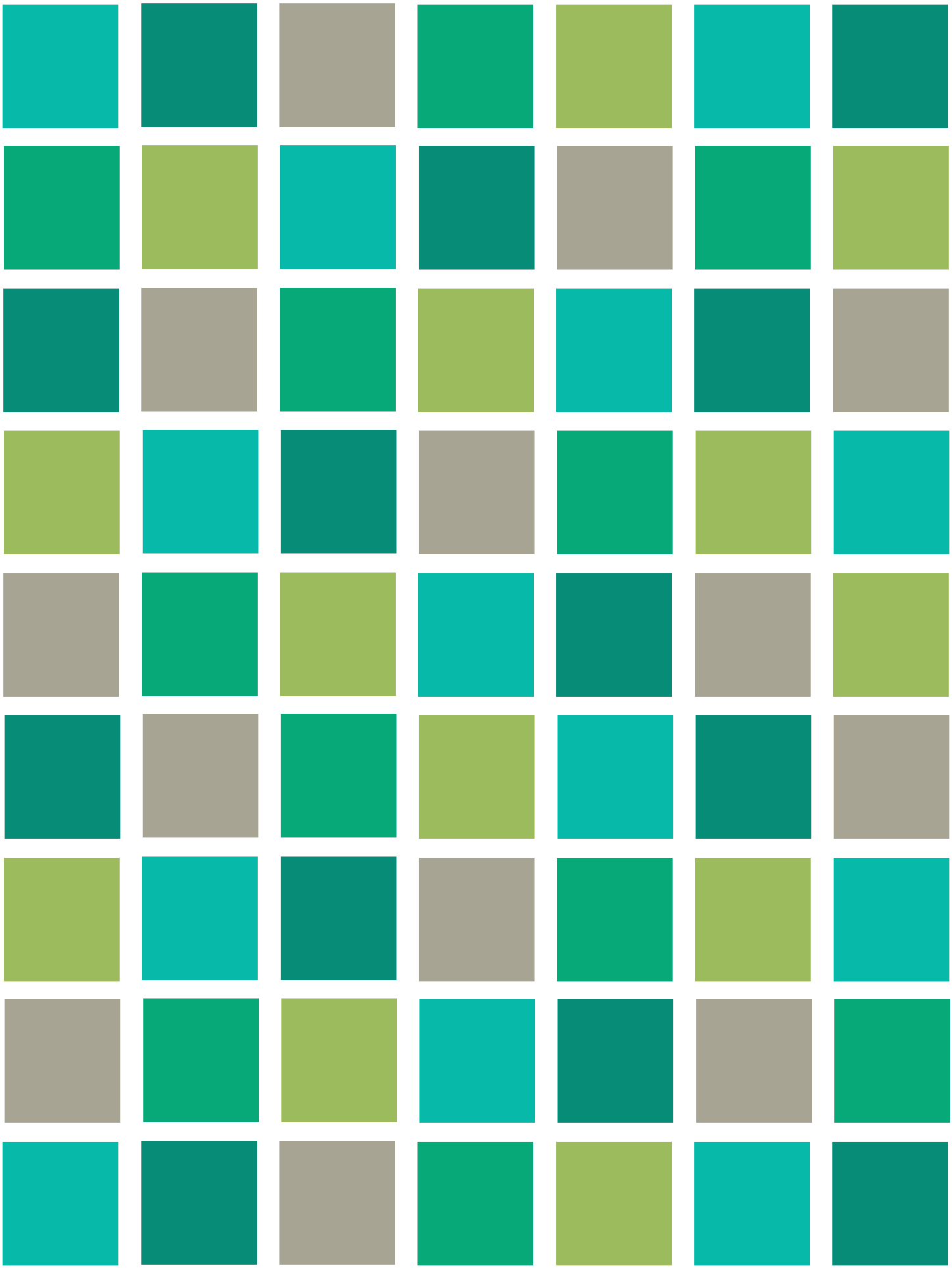
In this environment, the cyclical rebirth of the building becomes a driving force keeping technological innovation & sociological understanding participating & impacting the local community on a daily basis.

key words

Architecture, Sustainability, Designing for Deconstruction, Adaptability, Sociological Impacts of Architecture

problem statement

How does modern society influence the design intent for the life-cycle of a building?



1 statement of intent

typology

Research Facility for Portland State University's Institute for Sustainable Solutions (ISS)

claim

If the built environment were able to adapt over time, it would be able to maintain its viability.

ACTOR. the built environment
ACTION. adaptation
OBJECT. the building
MANNER. increased functionality & efficiency
STAGE. the place

premises

A building will not only structure one's environment, but present the opportunity to push the community towards further adaptation & innovation as it grows.

If a building is capable of adapting over time, it will have the opportunity to maintain the highest efficiencies in both function & available sustainable technologies.

Within this ability to adapt, we have the potential to lengthen and improve the quality of a building's life-cycle.

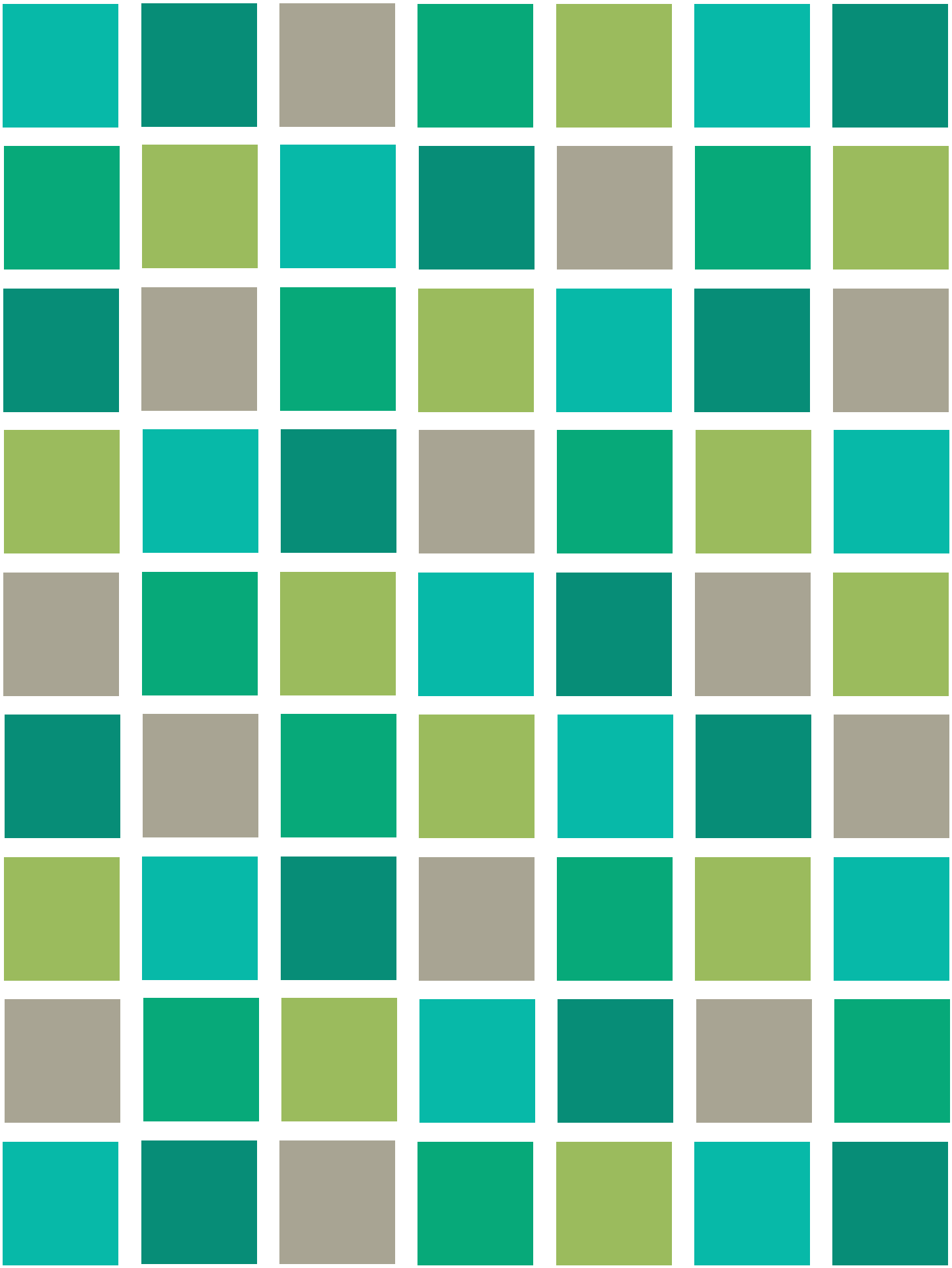
Buildings capable of changing to maintain or increase their efficiencies & functionality may then create impactful dynamic relationships between themselves & their surrounding community.

unifying idea

It is through the witness of others that we, as social creatures, learn. Using the strategies of adaptable, interactive, and innovative architecture gives great opportunity to enrich & educate surrounding communities.

justification

It is the responsibility of all design professionals to educate & enrich the surrounding community that they work within.



2 proposal

narrative

Through the investigation of the problem statement, an in-depth analysis will be made concerning contemporary ideas towards adaptive building spaces & technology life-cycles. It is imperative that society looks towards innovative technologies, which accommodate extended life-cycles and uses of building technology, in order to maintain a growing society.

The intention of this project is to educate those in the surrounding community of the contemporary solutions at work in the world today concerning building growth. As individuals witness & participate in adaptive buildings, they may themselves become more accustomed & interested in sustainable and innovative technologies in the world today.

Through this enlightenment, adaptable architecture may become a mode of inspiration for surrounding individuals to educate and improve themselves and the communities that they exist within.

Adaptable architecture, then, may have the opportunity to create significant social changes by leading through example in dealing with preventative solutions to potential future problems.

As architecture structures one's environment, it also structures one's sociological response to a space. If this impact can be used to better an individual or society, it should be used to help preserve the built environment which we all exist within.

The Institute of Sustainable Solutions (ISS) is one of Portland State University's newest programs, opening in the fall of 2010. Previously known as PSU's Center for Sustainable Processes and Practices, the Institute has changed their name to communicate the new leadership of the program since its opening in 2006, hiring Dr. Robert Constanza, previous director & Professor at the Gund Institute for Ecological Economics at the University of Vermont, to lead the program.

funding

In 2008, the James F. and Marion L. Miller Foundation gave PSU a 10-year, $25 million challenge grant for sustainability to be administered by ISS. The investment, to be matched every year, was created with the intention to motivate long-term investments ensuring the program's initial successes.

publications

ISS is also the new home to the journal Solutions, co-founded by the department head, Dr. Robert Costanza, with Paul Hawken, David Orr and John Todd.

staff

The Institute's administration consists of eight positions: Director, Associate Director, Program Manager, Financial Manager, Program Administrator, Sustainability Leadership and Outreach Coordinator, Head of Communications for Sustainability Initiatives, and Interim position for the Development of Sustainability Initiatives.

ISS has six full-time faculty positions, as well as two visiting specialists acquired through the Visiting Scholar Program. The Visiting Scholar Program was designed to enhance collaboration between academic institutions as well as to ensure the cross-pollination of ideas between campuses and geographies (Portland State University 2010, under 'Visiting Scholar Program').

user/client description

curriculum

The Institute offers a Graduate Certificate in Sustainability, which contains a minimum of 22 post-baccalaureate credits pertaining to the environmental, social, and economic aspects of sustainability. The program's coursework is separated into two parts in order to provide each student with an opportunity to learn about sustainability in multiple realms & depths.

The first part of the program investigates sustainability in a broader sense, as students of multi-disciplinary backgrounds investigate contemporary concepts of sustainability. The second part of the program allows students to focus on sustainable issues within their particular area of study.

Individual disciplines eligible for study are divided amongst two central ideas: water supplies & sustainable urban communities. This presents the opportunity for focused study within the realms of environmental, social/cultural, and economic studies. More specifically, in regards to water supplies, students may work to create integrated models used to assist in understanding complex river systems, the ecosystems they provide, and how to optimize shared uses. Students interested in more social and economic focuses may study subjects like green building, ecodistricts, sustainable mobility, renewable energy, green economic prosperity, natural capital, and social equity issues (Santen 2010, under 'PSU's New Sustainability Institute Takes "Solutions" Approach).

major project elements

classrooms

Due to the wide variety of courses to be taught at the Institute, the classroom spaces will need to be exceptionally versatile in order to be adaptable to different uses. Classrooms will need to be able to vary in size, materiality, and function in order to accelerate the hands-on learning style of the Institute. There is also a need for multiple break-out spaces to accommodate for smaller group meetings.

specialty spaces

Specialty spaces will be needed as the second half of the program focuses on the particular applicability of sustainable theory & technology for each student. Engineering students will have their own labs, as will students of environmental science backgrounds. Students interested in economics will have their own classroom/office spaces, while students in the fields of architecture, landscape architecture, and urban & community design will be given studio spaces, as well as access to a woodshop.

auditorium(s)

Every semester, the Institute organizes and funds several seminars presented by individuals involved in sustainable aspects of a multitude of fields. The building will need to have a large auditorium in order to accommodate presentations like these, among others.

computer labs

Due to the technological inclination of the programs offered at ISS, there will need to be several computer labs available to all students.

office spaces

The Institute will maintain administrative & faculty offices on the premises in order to ensure proper communication and interaction with the students. These spaces will include individual & shared offices, a break room, & spaces for meetings to take place.

study spaces

For the convenience of all ISS students, there are to be several study spaces located throughout the building in order to provide an accommodating environment for students to be productive while passing time.

library / resources

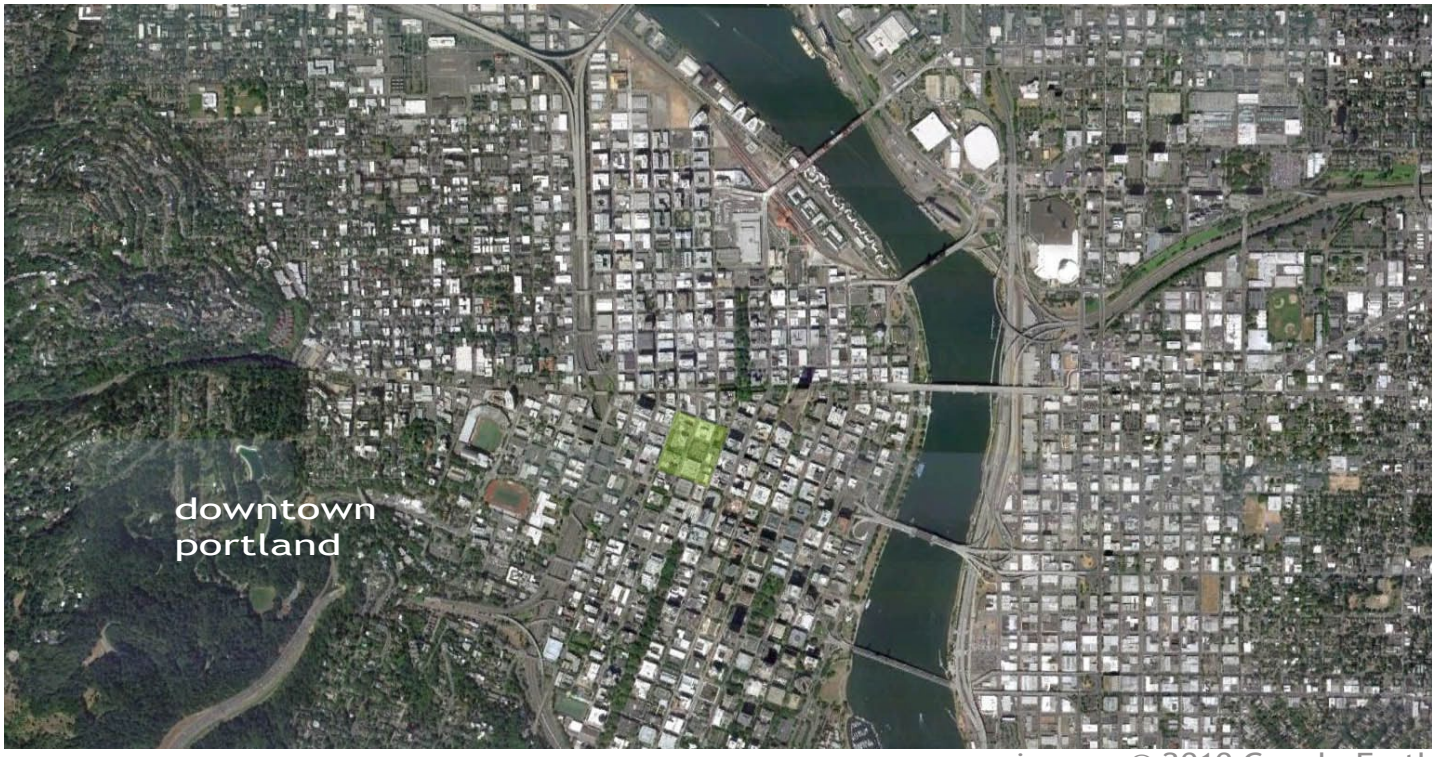
In order to educate the students to the best of the Institute's ability, there will be an on-campus library containing extensive research materials, as well as material & technology labs.

major project elements

exterior spaces

Due to the high rates of mass transit used throughout the city, the site intends to accommodate bike storage, as well as access to the building as oriented towards the rail line's stop. The site will also provide enough parking in order to accommodate for the existing public parking, as well as the increased activity from the Institute.

The intention of this design process is to create a model for a potential future of architecture. Through this, it is important that the site be experienced by a larger population than simply those at ISS. The intended response to this is to create a qualitative public plaza within the site, as well as accommodating for the food vendors currently situated along the souther perimeter of the site.



site information

region

Oregon is located on the northwest pacific coast, sharing borders with Washington, Idaho, Nevada, and California. Portland, a city of under 550,000 people, is located about two hours inland from the Pacific coast along the Columbia River Gorge. The gorge was formed by glacial floods following the eruptions of hundreds of volcanoes within the Cascade Mountain Range, dating from as much as two million years ago. This resulted in the creation of a 1,200 mile long river designating the border between southern Washington and northern Oregon (USGS, 2001).

city

The Portland metro area is centered along the Willamette River, a major tributary of the Columbia River. The city's average rainfall consists of approximately 42.1" a year, varying from drier summers into wetter winters, including an additional average of 6.5" of snow each year. The climate in the summer generally ranges from 50-80°F, with extreme highs approaching 100°F. The area's winter climate typically ranges from 40-60°F, with extreme lows approaching 0°F (NOAA 2010).

Portland's demographics include an ethnicity majority of Caucasians, consisting of 79% of the area's population. Subsequent ethnic groups of African Americans, Asian Americans, and Hispanic individuals each consist of under 7% of the total population. The city's average household income is just over $40,000, with a per capita income of under $23,000 (US Census Bureau, 2006).

Portland has recently been found to have the 6th highest literacy rate of cities in the nation of cities with populations

greater than 250,000 (Big Think, 2010). Recently, Dr. Jack Miller conducted a study correlating trends of literacy & sustainability, finding that cities with the highest literacy rates are also the greenest. Subsequently, cities with the highest literacy rates were also found to be safer & healthier in general.

neighborhood

The proposed site consists of one square block, three blocks south of West Burnside Street, a central collector street of downtown. Within a two block radius, the area has exceptional amenities.

Adjacent to the northeast corner is O'Bryant Square, a park of urban landscape, sculptures, & murals. Across the street from O'Bryant Square is a police station, increasing the security throughout the neighborhood. The site is also located three blocks away from Pioneer Square, a central downtown attraction & location of the Portland Visitor's Center. The Oregon Symphony is located across the street, as well as the City Club of Portland & several other retail and restaurant businesses scattered throughout the surrounding blocks (Google, 2010).

site information

As the site exists today, it is a centralized location for street vendors, making it a highly trafficked location throughout the work day. The site is located two blocks east of the Green and Yellow rail lines and one block east of the downtown streetcar, centrally located within the downtown 'Rail Free Zone'.

Due to the surrounding amenities, there are people located around the site at all hours of the day & night, suggesting a highly secure area for the students of the institute.

site

The existing site is currently used as a ground-level parking lot, scattered with a perimeter of numerous street vendors & trees, all of which are intended to be accommodated without interruptions in the final design.

The site is located nine blocks west of the Willamette River and in the center of the rail free zone. The streets on the northern and southern borders of the site are Southwest Washington & Southwest Alder, respectively; eastern and western borders are Southwest 9th & 10th Avenues respectively.

project emphasis

This investigation's intention is to explore the notion of a building's life-cycle. As developments age through time, they become less efficient and functional. It is important that in the near future we are prepared to deal with the onset of problems such as overpopulation, limited land availability, and natural resource depletion.

There is a need to re-investigate the intended life-cycle of a building, including the components used to construct one. This project intendeds to investigate the applicability of building materials, as well as the ability to design for their reallocation and preservation. Buildings that are designed according to their deconstruction create the ability to re-use building materials and allow for the initial building to adapt itself to new uses and functions.

This project will examine the ways to most efficiently maintain materials so they may be used in subsequent projects or applications. The investigation also includes structural assemblies which accommodate the use of such materials. Through a design that is capable of a certain amount of malleability, the building will then have the potential to maintain its functionality through its adaptation.

plan for proceeding

In order to ensure this project's validity, extensive research will have to be accomplished. Case Studies will be used to further understand contemporary solutions to similar architectural elements such as typologies, building functions, technologies, and theoretical premises. The site will be investigated on a multitude of levels, ranging from the human scale of the development, to how it relates in full to its local & regional environment.

The research will be conducted using the mixed method qualitative/quantitative approach. This research approach will accommodate a holistic understanding of design strategies to be incorporated into the project. By using the Concurrent Transformative Strategy, the research will yield information of both quantitative and qualitative elements, represented simultaneously in both graphic and literary forms.

In order to communicate the entirety of the design process, all materials produced will be electronically documented. This includes productions of all sorts of media, ranging from BIM software creations, photography, hand-drawings and sketches, and physical models of all levels of presentation. All documented work is to be frequently updated & backed up as to not lose any information due to technological downfalls. In the finality of the premise investigation, the design conclusion will be presented in a series of graphics communicating the spatial organization and interaction of the project.

studio experience

STUDIO I. Undergraduate
Darryl Booker
Tea House (Fargo, ND)
Mississippi River Rowing Clubhouse (Minneapolis, MN)
Rocky Mountain National Park Dwelling (RMNP, CO)

STUDIO II.Undergraduate
Joan Vorderbruggen
Montessori School (Moorhead, MN)
Prairie Dance Academy (Fargo, ND)

STUDIO III.Undergraduate
Steve Martens
Inuit School (AK)
Children's Clinic (Minneapolis, MN)

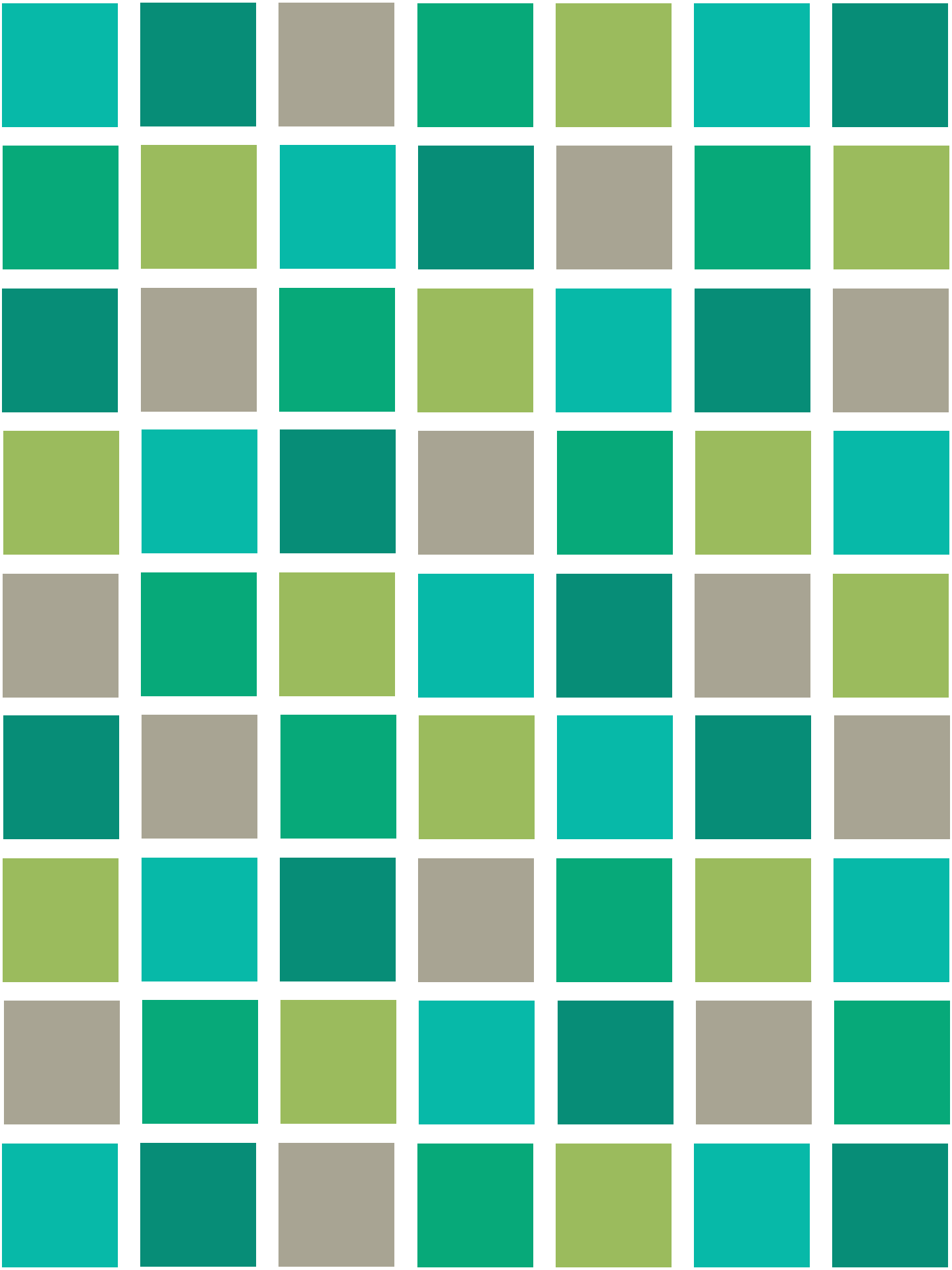
STUDIO IV.Undergraduate
Ronald Ramsay
Conservatory / Mixed-Use (Fargo, ND)
Record Label Headquarters (Chicago, IL)

STUDIO V. Undergraduate Capstone
Bakr Aly Ahmed
Mixed-Use High Rise (San Francisco, CA)

STUDIO VI.Undergraduate
Frank Kratky
Darryl Booker
Urban Design (Santo Domingo, Dominican Republic)
School House (Tanzanyika, Africa)
Slum Re-Development (Santo Domingo, Dominican Republic)

STUDIO VII.Graduate
Cindy Urness
Minnesota Experimental City Agricultural Mid-Rise (Millerville, MN)

STUDIO VIII. Graduate Thesis
Darryl Booker
Adaptable Architecture (Portland, OR)



3 program

research
results
& goals

theoretical premise/ unifying idea research

Cradle to Cradle
Designing for Deconstruction
Sustainable Technologies

cradle to cradle

'Cradle to Cradle' is a contemporary environmental movement pertaining to the intended life cycle for the materials we create. As we only consume a minority of the things we buy, there is a need to re-assess what happens to things once we delete them from our lives.

In the 2002 book, *Cradle to Cradle: Remaking the Way We Make Things*, William McDonough & Michael Braungart bring attention to the contemporary way of designing products as minimal-cost universal applications to individual needs. The design of these products has created a tunnel-vision where society views their applications as limited in both function & life. Products are created, used, & thrown away; limited to a life-cycle of birth, one life, & death - *cradle to grave*.

Because of this limited life-cycle, products are only being designed for cheap production & their immediate consumption. Disposal is not accounted for in the product design. Because of this limited insight into product consumption, problems arise such as pollution & societal health, un-used nutrients, & limited resources.

It is through this insight that an alternative way of thought is proposed: *cradle to cradle*, as opposed to the previous c*radle to grave*. There is a contemporary societal sentiment of celebrating reduction, which only sustains the detriment caused in past decades- rather than correcting it. *Cradle to Cradle* calls for an effort to correct these problems by correcting the way we think about the products we consume.

research results & goals

What *Cradle to Cradle* suggests is a need to understand the entire process of a product, from the beginning & past its end, presenting an opportunity for cyclical rebirth.

Currently there are several products designed from solid materials which, in a gaseous state, are illegal substances to the United States. However, the products are built & packaged in other countries, where the materials are still legal, & shipped to the United States without thought to what will happen in the product's disposal (ex. leaking atmospheric contaminants upon incineration).

Cradle to Cradle challenges society's attempts to be 'green' by demanding to include more in the discussion. Reducing, reusing, & recycling is not enough to create products which respect our quality of life.

In this book, McDonough & Braungart discuss two buildings; one is of the highest technologically sustainable standarts, the other is a passive design attempting to accommodate for similar energy efficiencies as the first. The juxtaposition occurs as the latter building uses what materials it can to passively accommodate for what the first building needed to incorporate entire systems accomplished. In this passive design, materials are used in a holistic application, giving the potential to further its accomplishments through further incorporation of sustainable technologies.

It is necessary that contemporary society look at our resources in the holistic representation of their life. Their harvest, their use, and their re-allocation of resources (Braungart & McDonough, 2002).

designing for deconstruction

According to the US Environmental Protection Agency, the US produces nearly 160 million tons of annual building construction-, renovation-, and demolition-derived wastes, accounting for nearly one-third of the nation's non-hazardous solid waste generation (EPA, 2008). These materials are then seen as waste & discarded into landfills, creating additional problems of solid waste management.

Because of this, there is an alternative approach to building design that is becoming more & more popular: designing for deconstruction. In this perspective, buildings are designed to accommodate for an easier disassembly in order to maintain the materials for re-allocation in other projects.

Designing for deconstruction presents the opportunity to curb issues caused by building development such as waste & pollution. The building & material life-cycles then become cyclical in nature, processing between materials & their applications.

In designing for deconstruction, there are several principles that may be accommodated to expedite the process. One way is to design a simplistic structure & form. Simplicity of structural systems, forms & grids allows for ease of construction & deconstruction in increments.

From this starting point, further interchangeability of light-weight, modular materials can expedite the process of reuse and reformation.These materials may also use minimal amounts of chemical adhesives, using bolts & screws instead to ease in the facade's deconstruction.

research results & goals

A building's structral integrity aids in its ability to be deconstructed. Long spanning posts & beams allow for reduced interior structural elements, ensuring stability during envelope alterations. Furthermore, grouping components based on life expectancies can simplify the act of deconstruction, in its need & application.

Different types of building materials allow for different opportunities of deconstruction. Masonry construction presents the opportunity for de-panelization for reuse of large areas or utilizing mortar in the separation process.

Concrete materials allow for expedition of non-cementitious materials from the concrete plates, and despite its inflexible nature for reapplication, concrete is readily recyclable & therein a priority for material reuse.

Lumber presents the opportunity to reuse a significant amount of building materials as well. By using bolts to assemble the structure, entire wooden posts & beams are able to be recovered for further building applications. By interacting with a simplified framing system, centralized structural framing systems may be designed to be self-supporting, aiding in the deconstruction of other parts.

Flat roof systems allow for ease of access in panelized roof removal. Depending on the construction of the roofing system, a flat roof may use more sealants & chemical bonds raising the difficulty level of deconstruction. High-sloped roofing systems create a larger difficulty in their access points for deconstruction, however are typically constructed in a more modular fashion (Guy & Shell, 2002).

There are several benefits received from designing for deconstruction. In monetary perspectives, there is the immediate gain in that buildings designed for deconstruction typically use less material, creating minimal opportunities for construction mistakes, along with minimizing construction & labor costs due to design complexity. Further savings include the dismantling of building appendages due to the incorporation of the building's deconstruction in the design (Ciarimboli & Guy, 2008).

The modular design style of building facades also creates an ease for adding several types of sustainable features, as well as presenting the opportunity to adapt spaces to alternative trends of use, preserving the functionality of a building rather than deeming it no longer useful.

Once materials are removed, they may be re-allocated, sold, or donated towards qualifiying charities resulting in a tax benefit (EPA, 2010). The minimizing of waste then leads to a smaller need for waste facilities, minimized consumption of virgin resources, & more functional & efficient buildings.

ecorock

In 2008, Popular Science awarded its GreenTech Grand Award to EcoRock, the first environmentally-friendly alternative to gypsum. Gypsum has been in use with little-to-no competition since its invention in 1917.

Gypsum drywall production is the third largest greenhouse producer in the building materials industry, an industry responsible for 52% of total, worldwide greenhouse gases. As car exhaust creates 9% of total greenhouse gases, replacing one gypsum drywall plant with an EcoRock plant is equivalent to taking 65,000 off the road (Serious Materials, 2010).

In addition to greenhouse gases, EcoRock is made of an assortment of 20 materials, 85% of which are industrial by-products. The materials react chemically when mixed with water, binding together into a congealed paste poured into sheets. This method uses 20% of the energy used in gypsum production, while outperforming its abilities to hold off termites & mold by at least 50% (Popular Science, 2008).

Finally, EcoRock has been designed for reuse following its application as a building material. EcoRock can be used as a pH additive for soils, may be recycled and used as raw material for further EcoRock production, and may be safely disposed of in landfills, unlike gypsum (Serious Materials, 2010).

nano vent skin

Nano Vent Skin is a building envelope material which uses organic photovoltaics to capture sun, while micro wind turbines capture wind. NVS presents the ability to cover the entire exterior of the building, maximizing surface space while its modularity allows for easy building applications on several scales. Additionally, the superstructure of NVS incorporates bio-engineered micro organisms intended to consume CO2.

Nano Vent Skin is a zero-emission tubular grid material, allowing for maximum consumption of renewable energy on a micro-scale. The outer skin presents the ability for solar gain through photovoltaics, while the micro turbines use 'polarized organisms' to create chemical reactions, generating power upon contact with the structure. The bio-engineered micro organisms then attempt to purify the environment, consuming CO2 from the exterior air (Chino, 2008).

NVS attempts to create a balanced incorporation of renewable energy & anti-pollution exercises, while also notifying maintenance of errors or failures. When one of the turbines is found to be faulty, a signal is sent through nano-wires to the central system, while micro organisms are sent through the tubes in order to regenerate the area with a self assembly process (Alter, 2008).

soltech

SolTech Energy System has released a residential-scale glass roof tile which is capable of producing heat. Unlike most tile-heating products which heat up water or vacuum pipes, the SolTech Energy System uses clean air.

The tiles, made of ordinary glass and weighing no more than those made of clay, are installed on roof joists above black nylon canvases, above mounted airslots.

The black canvas is then used to absorb heat from the sun, forcing the air to start circulating. The hot air is used to heat up water, which is connected to the house's heating system through an accumulator.

The SolTech Energy System generates about 350 kWh per square meter depending on climate, slope angle, & cardinal direction (Jeppsson, 2010).

proSolve370e

ProSolve 370e are air-pollution reducing architectural tiles. The tiles are intended for either post- or pre-construction elemental usage on building facades. ProSolve 370e are made of recycled ABS plastic with a titanium dioxide (TiO2) nanotechnology coating. When exposed to sunlight, the TiO2 combats and neutralizes both Nitrogen oxide and Nitrogen dioxide (Fuad-Luke, 2008).

Although TiO2 has been known for its purifying qualities since its conception in the 1970's, ProSolve is claiming higher efficiencies than in its previous uses. Due to the large amount of surface area exposed to sunlight on each tile, a smaller & more compact sculpture is capable of having similar effects to that of a larger piece with less light exposure (Hendry, 2010).

Grune Wand GreenWall System

The Grune Wand Green Wall system was designed to be a beneficial addition to indoor environments. The system's intention is to benefit individuals by exposing them to plants in their work & living environments, providing an exceptional indoor climate. The modular system consists of a high-grade steel internal structure with substrate panels. The plants are cultivated in a nursery prior to their installation (Fuad-Luke, 2008).

The watering system is carried through a resevoir that runs either up or down the interior of the wall, collecting in the substrate panels. Because of the inorganic materiality, the potential for mildew & mold is minimized.

This low-maintenance system has several measurable benefits as well. The wall system is capable of reducing CO2, while simultaneously producing oxygen. Furthermore, the system reduces dust & other air contaminants while increasing humidity in winters resulting in fewer colds and cooler air in the summer caused by evaporation (Architonic, 2010).

theoretical premise/unifying idea research

research results & goals

summary

In reflection of contemporary strategies that accommodate an increased or altered life-cycle of a building, it would seem that several applications are simply about incorporating on exceptionally passive system. Once that is accomplished, further technological solutions towards green building are to be added on the additional level.

It would seem, however, that the absolute most important way of allowing for versatility among spaces is the combination of passive design strategies & designing for deconstruciton. In designing for deconstruction designers have the opportunity to not commit to static spaces and accommodate dynamic programmatic requirements.

By weaving the theories of Cradle to Cradle & designing for deconstruction, a hybrid of a growing, adaptive, & regenerative building is clearly possible. The choice of building materiality, however, presents the ability to 'make or break' the success of these theories.

Building materials that are not only safe to use but safe & easy to unmount & dispose of will present a difficulty in this project. It will need materials like EcoRock, which are harvested & cultivated within sustainable atmospheres, while also accommodating for an ease of assembly and disassembly.

Further research will need to be accomplished for extensive knowledge of materiality life cycles & construction in order to maintain a complimentary & culminating design of these adaptable, regenerative theories.

research
results
& goals

typological research

Center for Sustainable Energy Technologies
Turkcell Research & Development Center
California Academy of Science

summary

These case studies show the significant progress being made throughout the world in regards to sustainable design, modular design, & design using existing materials.

The Centre of Sustainable Technologies in China presents an excellent example of academic spaces that are used in a poetic, sustainable, and enriching way. The building excels in its ability to create a central focus, while maintaining its mixed-cultural integrity.

The building program separates private from public in an efficient and appropriate way, without alienating those who don't inhabit the spaces. The building is exceptionally poetic in nature. All of these aspects result in increased passive gain & energy efficiencies. The dramatic entry condition pulls people into glowing spaces, a spectacular & dynamic environment for the community, much like the entry condition to the Turkcell Research and Development Center in Istanbul, Turkey.

The Turkcell center has an exceptionally interesting and interactive entry condition, inviting workers to explore & experience the green roof. Furthermore, the design is extremely successful in the interior environment that it created for the workers of the building, adding in additional spaces, functions, & activities in order to enrich the lives of the workers, with the insight of increasing productivity.

research results & goals

The eastern facade of the building is an inspiring four-story wall of glass that minimizes the feeling of a separation from nature. As the building interacts with the site & the green roof rises from it, the architects spent a lot of time thinking of what is suggested by the existing topography, rather than forcing anything upon it. The impact of the green roof is not entirely unlike that of the California Academy of Science, mimicking San Francisco's rolling hills while also attempting to complement & hide itself within the park.

The Academy allows for an exceptional application of sustainable systems throughout every scale of the building, whether it be turbine-powered water faucets, or entire walls reused from the previous structure. The less appealing aspect of the building, however, is that it appears to have been designed without a budget, or, perhaps I simply don't see $488 million as being a conservative application of sustainable processes, almost ruining the argument for its necessity.

There are so many arguments against sustainable and green technologies due to their cost, and this building seems to only emphasize the argument. Yes, we could all design ridiculously sustainable structures given half a billion dollars, but perhaps there is more talent in using passive strategies as a more sophistocated way of understanding the green movement.

case study

Centre for Sustainable Energy Technologies

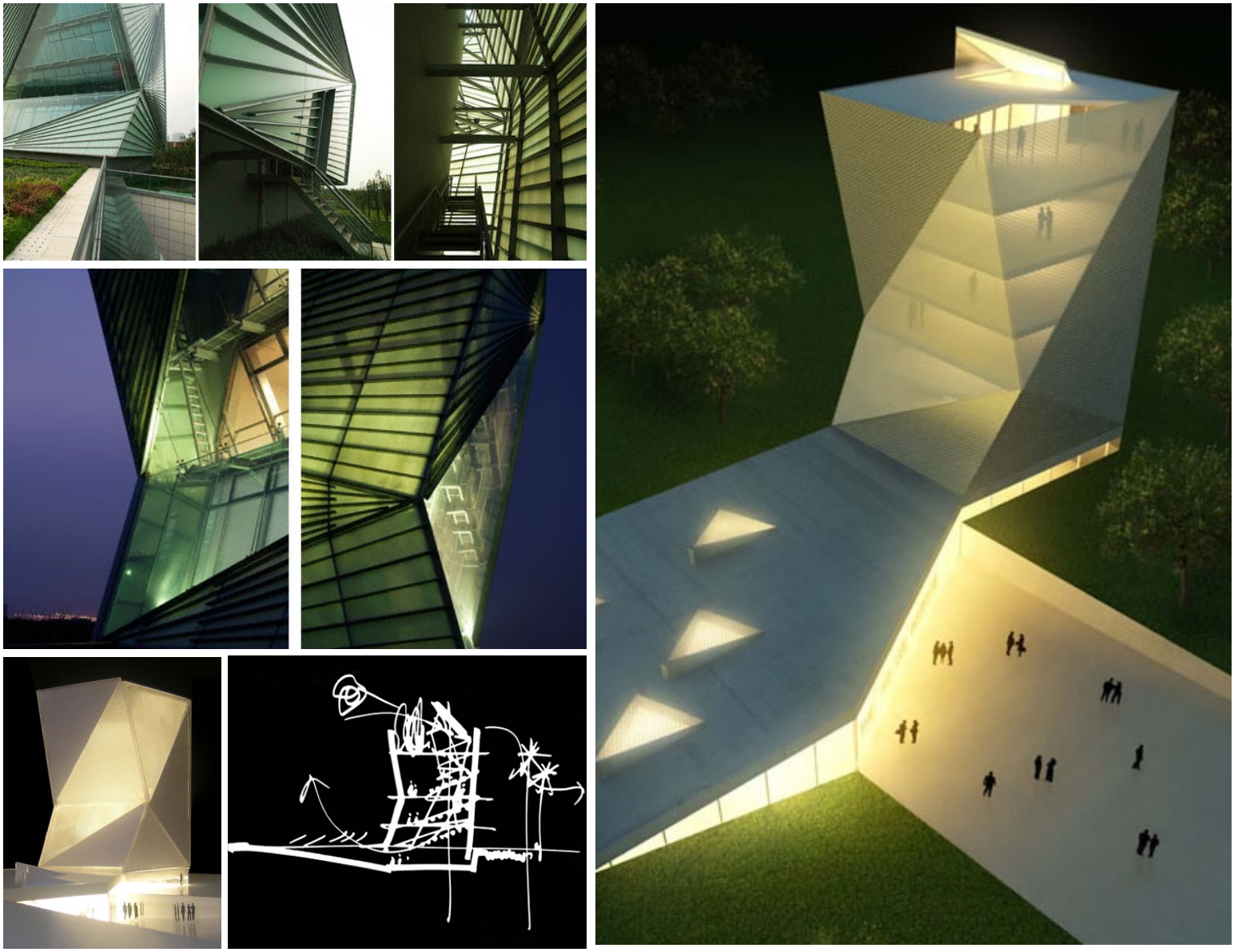
Mario Cucinella Architects

Ningbo, China

In 2008, Italian architects at Mario Cucinella designed a new facility for the Koo Lee Institute of Sustainable Environments, the Centre for Sustainable Energy Technologies (CSET). The Koo Lee Institute stands in the first independent campus in Ningbo, a city of 1.2 million people on the oriental coast of China (Salmi, 2008).

The Koo Lee Institute of Sustainable Environments operates under Nottingham's School of the Built Environment, setting forth exceptionally high standards for energy efficiencies which resulted in a design for China's first zero carbon university building.

The building design was originally designed under the poetic influence of traditional Chinese lanterns & wooden screens. The 22m high, six story building is composed of a double skinned glass facade, twisting as it reaches five stories above ground towards the sky.



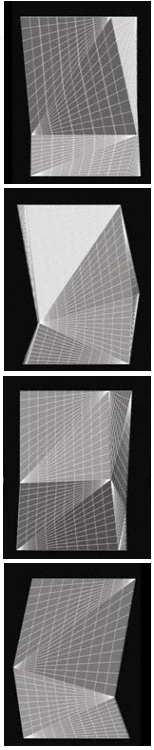
images © Mario Cucinella Architects

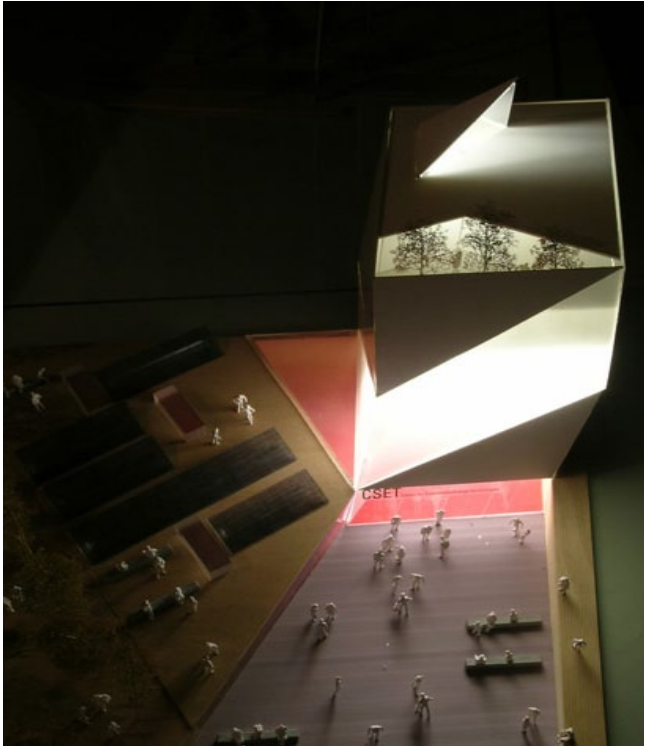
The main entry to the building is a ramp which sinks below ground level for a cavernous approach towards the reception area. From this centralized location, guests are able to circulate into the public exhibition spaces, or private scholastic spaces of workshops, labs, offices & classrooms.

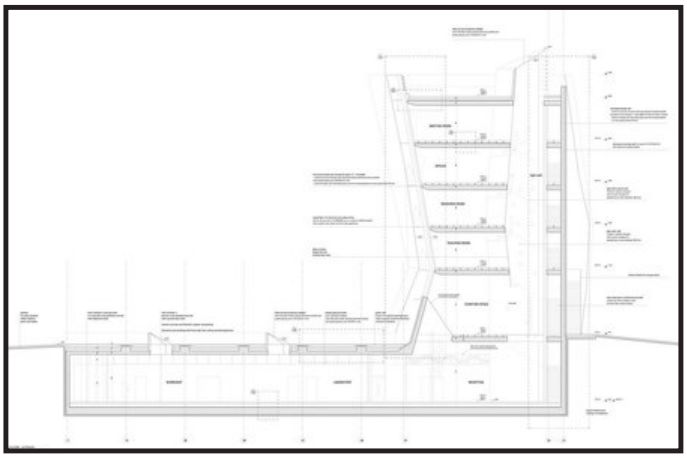
The glass facade & building skylights are used to bring fragments of light to all floors, as well as presenting the opportunity for passive ventilation through the large vertical space. The building was designed initially to accommodate extreme climates in both summer & winter.

The northern face of the building is sealed off from winter winds, while being partially open in the alternative cardinal directions for access to solar gain. The building's significant solar gain throughout the entire day minimizes need for artificial lighting.

The winding facade of the building creates opportunities for natural ventilation throughout the individual spaces of the building, connecting the interior spaces to the central vertical corridor, creating a more fluid exchange of fresh air.

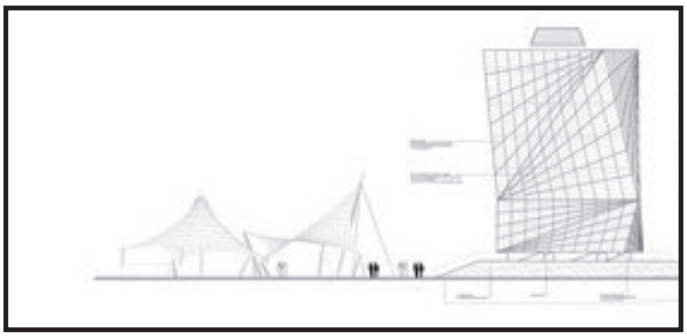


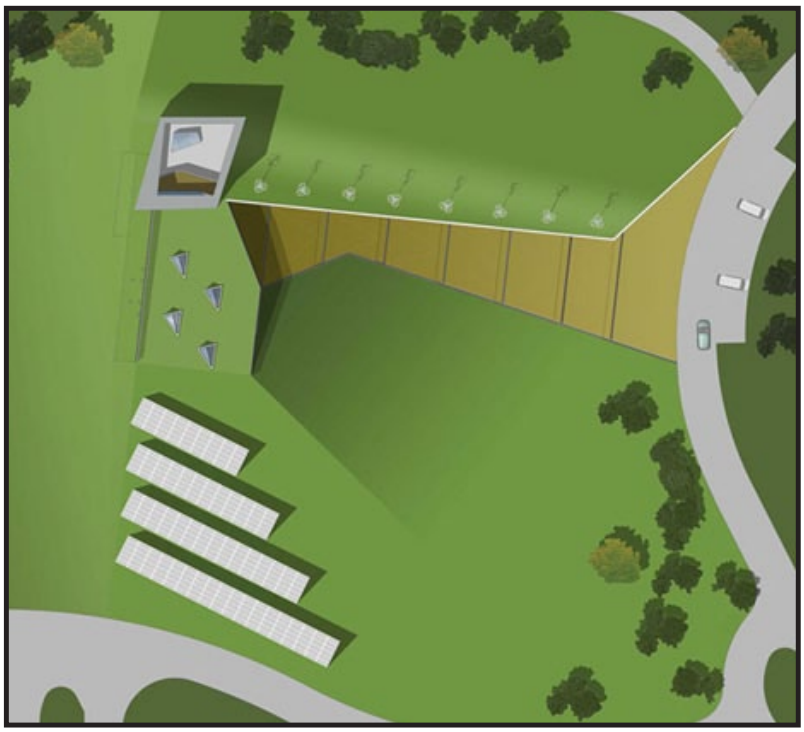


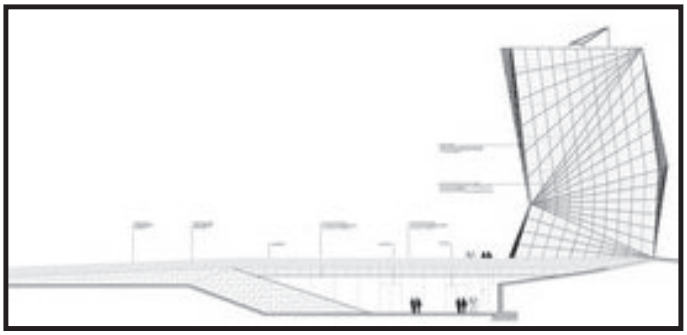


response

I find several aspects of this project to be remarkably excecuted. Beginning with the approach, the ground line pulls the visitors inwards as it sinks towards the entrance. In this way, using interactive green space as techtonics, the site maximizes its usage potential. The design therein provides a welcoming enviornment, whether interior or exterior.







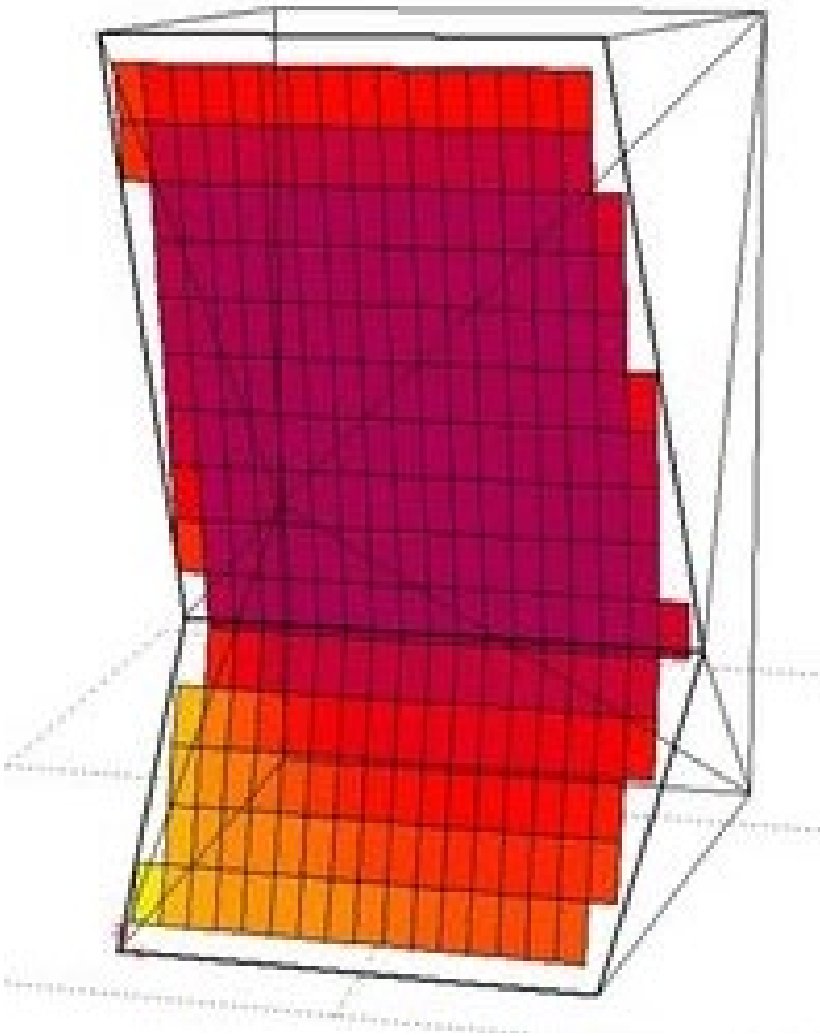


images © ArchitectureWeek.cz

The buiding is also exceptionally successful in its play of natural lighting. The vertical corridors not only give an exceptional access to daylighting, but the spaces are also consequentially opened up, creating a dynamic quality of the spaces in their form. Also, because of the varying angles of the facade, light exposure is more accessible due to the increased surface area.

The twisting facade compliments the design's inspiration of a japanese lantern, while also creating several modes of functional gain. The passive gain, however, is more than likely the most successful & beneficial metaphorical representation of the building design. As the building skin is intended for maximized solar gain, daytime hours allow for exceptionally lit interiors, providing relationships with the exterior environment. During the evening, the lighting access provides an exterior glow similar to that of a literal lantern.

As shown in the image to the right, the bending of the facades were designed in accordance with the needed density of sunlight, as well as to accommodate harsher winds. This design excels with maximum efficiencies while also intending strong aesthetic metaphorical values.



© Mario Cucinella Architects

case study

Turkcell Research & Development Center

Erginoglu & Calislar Architects

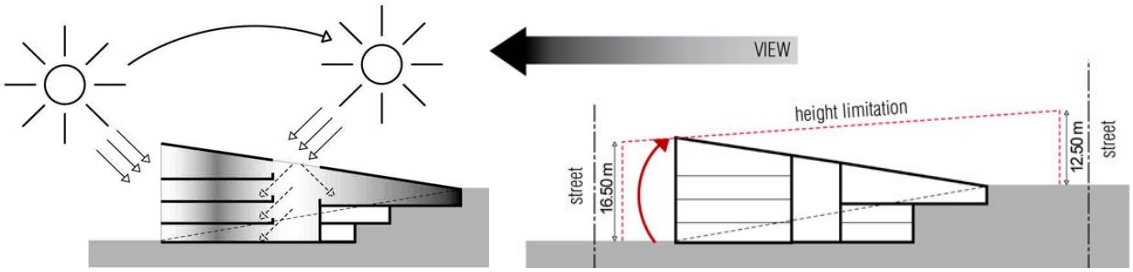
Istanbul, Turkey

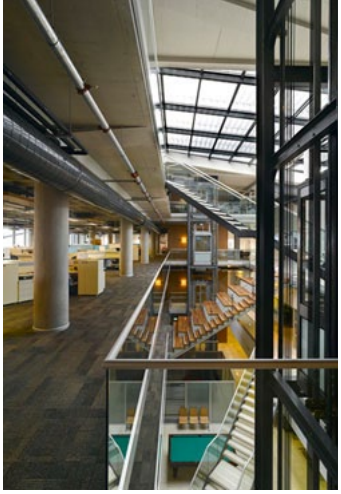
Turkish architects from the firm Erginoglu & Calislar have recently design a private research & development center in Istanbul, Turkey. The sustainable structure is located within the Tubitak Marmara Research Center Zone on the outskirts of the city.

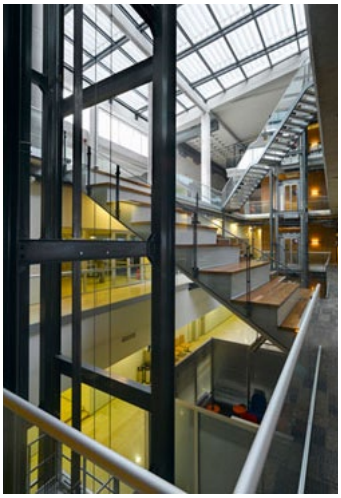
The four-story building has been designed with the mindset of including excellent viewpoints from all areas of the building, as well as making the spaces a low-energy, ecologically friendly environment.

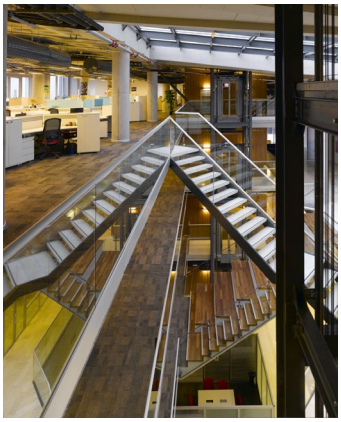
The trend of sustainability has not fully spread to Turkey as of yet, however, the architects did attempt to "try to catch the environment's spirit" in their designs. It is through this that the architects responded to both the intended building function and the environmental presence of the site.

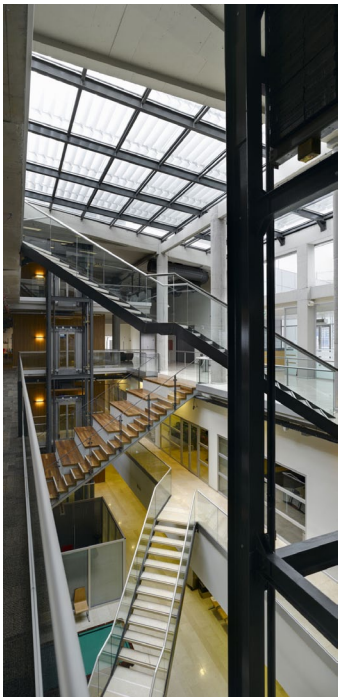
As one approaches the building, they are pulled towards the center of rising green roofs & metal facades into a central vestibule











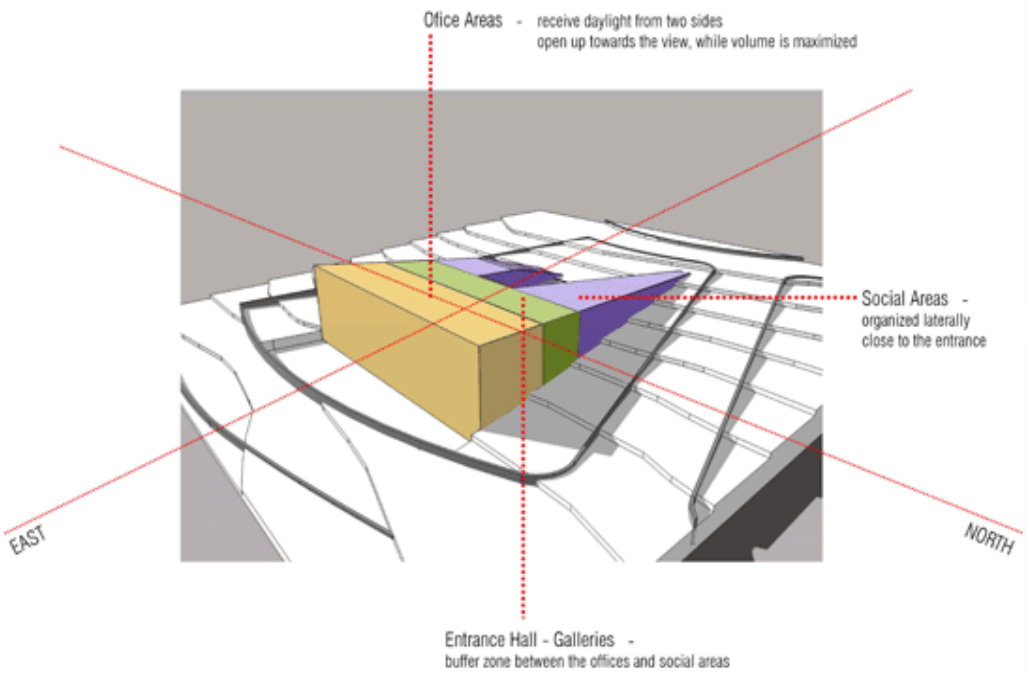
into an large entrance hall, which creates a buffer between office spaces & social areas reaching out in each direction.

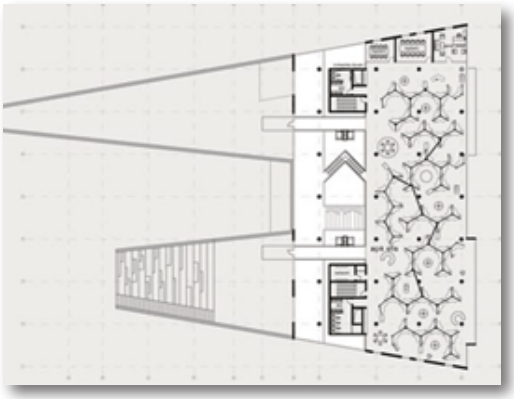
The building was designed with the site in mind, including the way it cuts through it, the viewpoints accessed, & the passive solar gain. The architects also attempted to accommodate the building's inhabitants: dedicated workers who travel significant distances to work every day. Because of this, the architects decided to include a variety of amenities, such as a fitness center, dorms, & even retreating projection screens for watching videos.

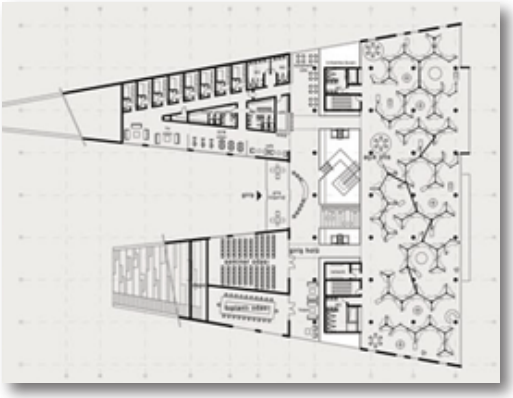
To accommodate for an improved work environment, the building has several different sources of passive lighting, also minimizing electricity costs. According to Calislar, to cater to the sloping site the architects used the existing slope to profit from the light and view. As the site reveals the building moving eastwards, so the green roof rises & offers an alternative environment for the workers to experience.

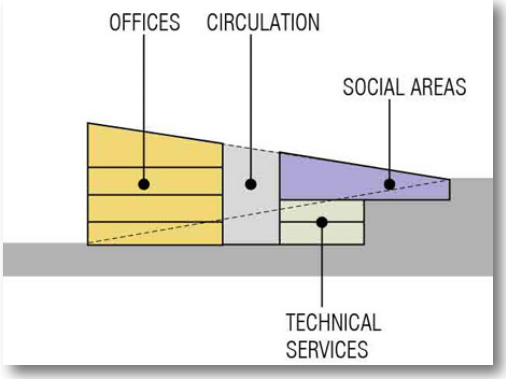
The eastern facade is a four-story glass facade with three extruded shapes to provide versatility in design. The side walls that cut through the site contain alternating angular nooks for solar gain & alternative viewsheds.

The building interior opens up to enable inhabitants to see a multitude of spaces, for the function of increasing communication throughout the company, says Isik Sungu, an architect employed by the firm. The attention to programmatic detail has led to a highly efficient & low-energy building of sustainable strategies & personal insight.







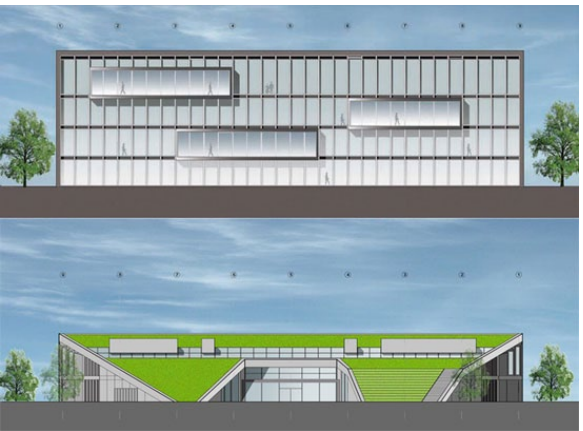


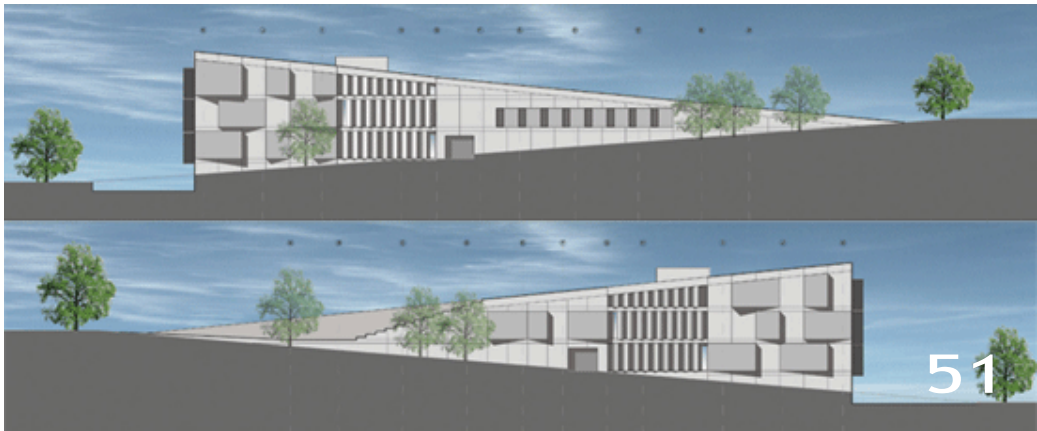
response

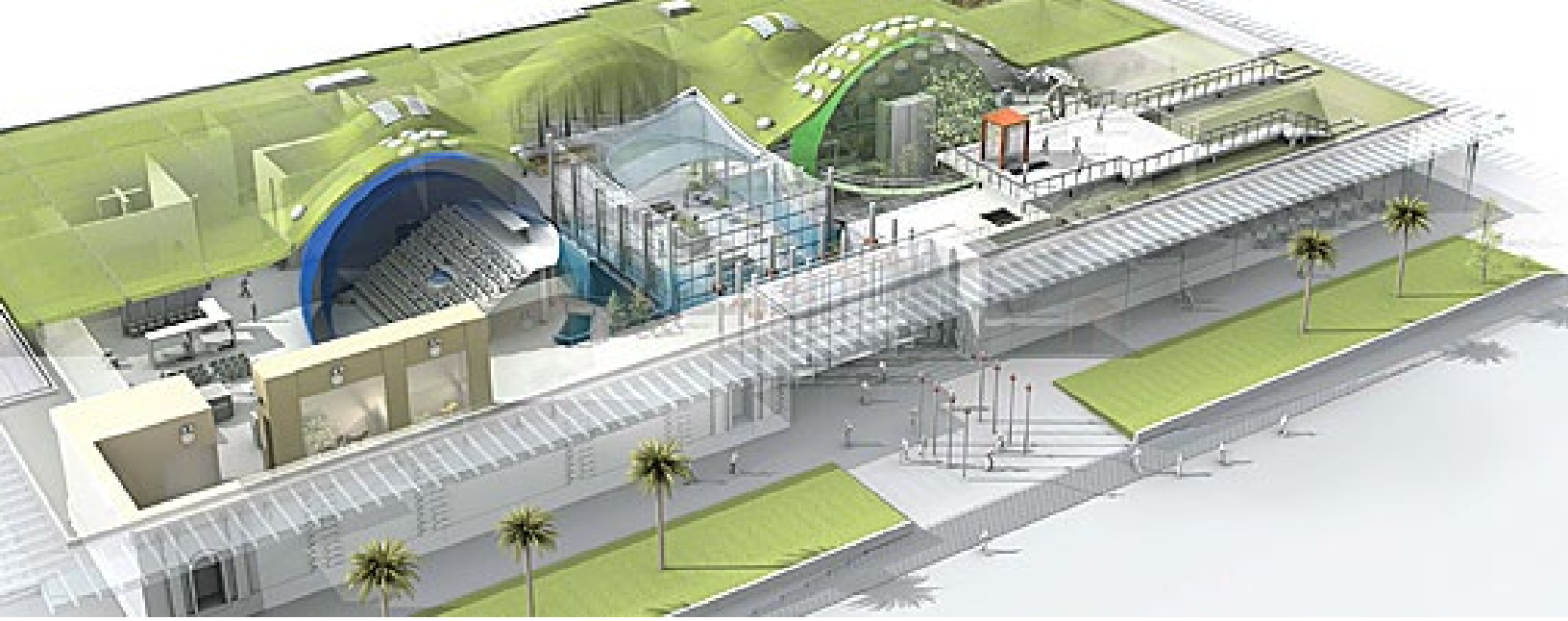
One of the most beneficial aspects of this design is the intention to maintain a productive environment for the workers of the building. This is expressed in several ways, beginning with the approach towards the building. As one approaches the entry, a symmetrical rise of green space grows on each side, accessible to individuals on the site for versatility of views. The back side of the building also provides for qualitative green space, including a paved patio at the lowest point of elevation.

The entry leads into a large centralized vertical corridor, circulating light, air, and an open social space. The centralized corridor creates a buffer between the private and professional sectors of the building, providing employees with an emotional recognization of comfort associated with spaces, an attempt to make the most pleseant environment possible. The building is oriented towards large amounts of sunlight with parts of the facade extruded to deliver generous daylighting & viewsheds.

Through all of this, the building creates a pleasant, passive environment catered towards the comfort of the inhabitants of the space. As qualitative environments increase productivity, this building is an exemplary example of how to accommodate for an efficient & comfortable work environment. The center provides an excellent example of how to accommodate passive design while attempting to create comfortable & productive environments.







© Bryan Christie Design

case study

California Academy of Science

Renzo Piano

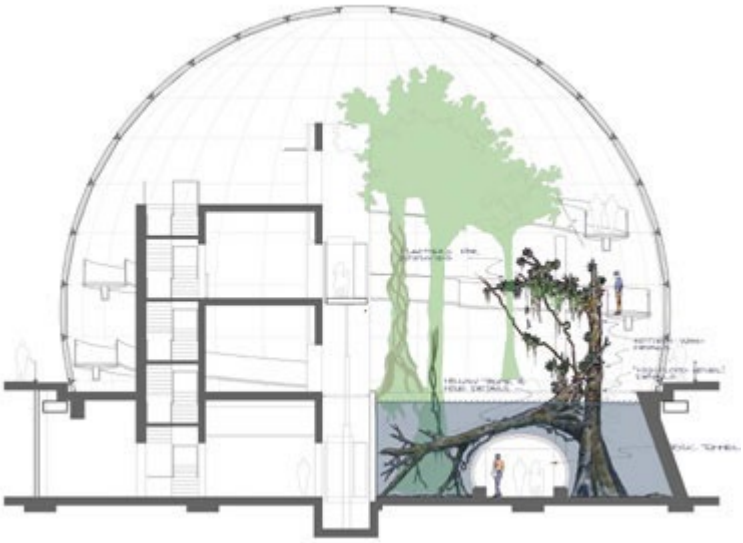
San Francisco, California

Beginning in 1999, the search for an architect to design the new California Academy of Science began. The project houses the Kimball Natural History Museum, Steinhart Aquarium, Morrison Planetarium, eight scientific research departments, and over 20 million specimens.

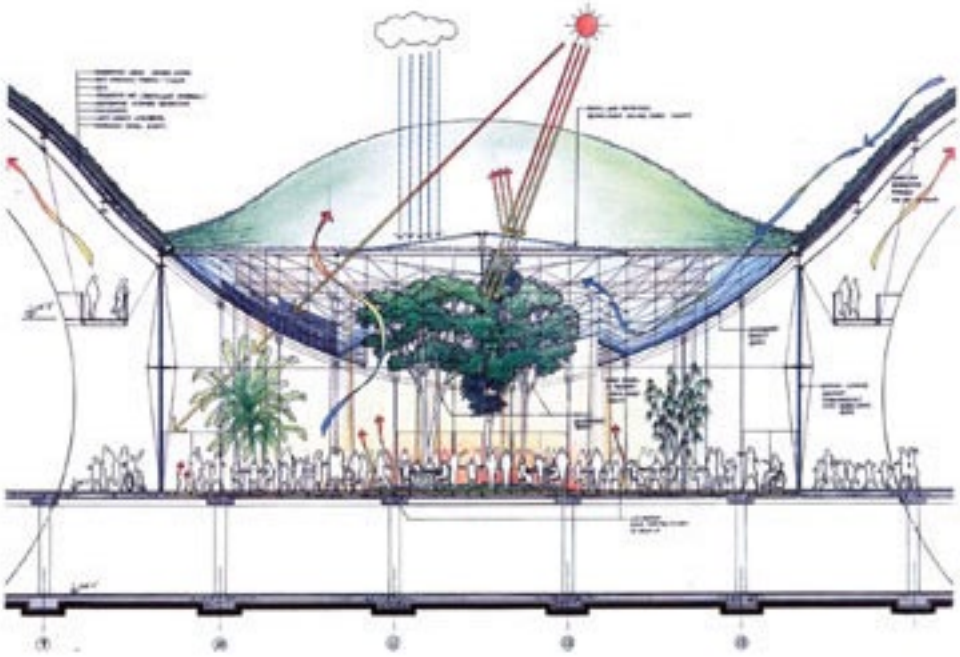
The Academy opened in 2008, located in the Golden Gate Park of San Francisco, across from Herzog & deMeuron's deYoung Art Museum.

The building conserves two walls from the previous building & is aiming for platinum LEED certification, exceeding 30-35% less energy than required by code. Over 90% of the previous building's waste was recycled, while a minimum of 50% of the new Academy was sustainably harvested, including all structural steel found throughout the building. Even the insulation of the building was made from recycled blue jeans, containing 85% post-recycled content while using cotton, a fast-growing renewable resource.

The building consumes a minimum of 90% passive daylighting, as well as electronic window systems which are programmed to open & close according to needed ventilation.



© Renzo Piano Building Workshop



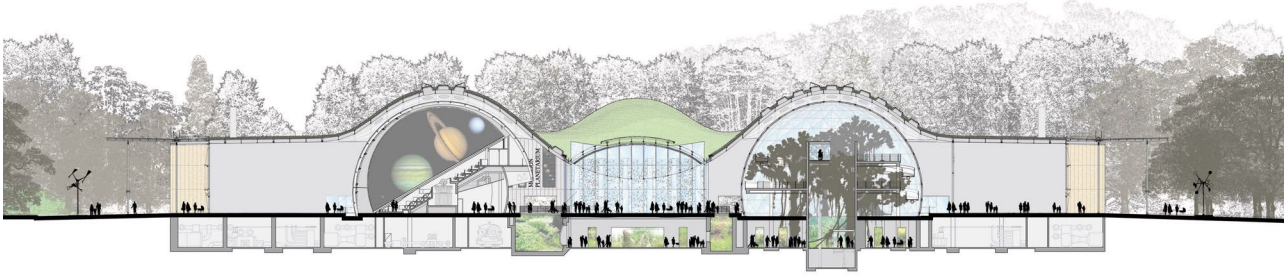
© Renzo Piano Building Workshop

Both significant ecosystems (living rain forest & coral reef) are designed with access to solar gain, while in larger, interior spaces there are photosensors that determine the need for artificial lighting.

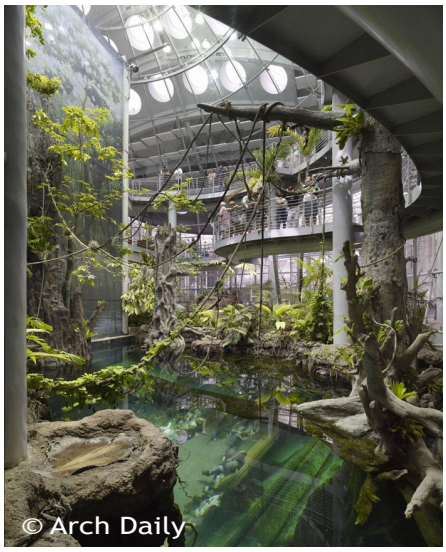
The building's 2.5 acre green roof aborbs rainwater, preventing up to 3.6 million gallons of runoff from carrying pollutants into the ecosystem each year (Saieh, 2008). The building also practices the systems of greywater, low-flow water fixtures, & pulls salt water for the Aquarium from the Pacific.

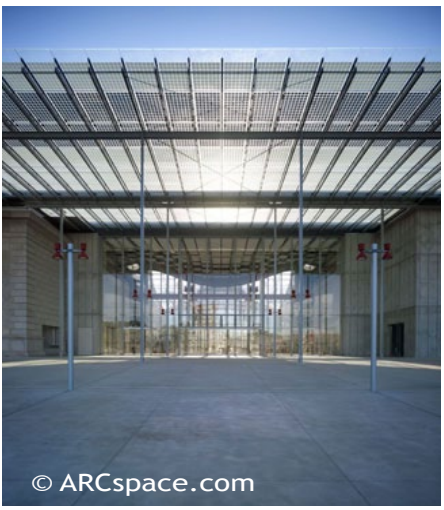
The green roof also acts as an 'ecological corridor' for wildlife, containing approximately 1.7 million plants that cover the roof, & becoming the largest swath of native vegetation in San Francisco (Saieh, 2008). Because of the diversity in plant life on the roof, there is a significant enrichment in the area's general biodiversity. The plants chosen for the greenroof were done so to accommodate for a variety of native insect's diets.

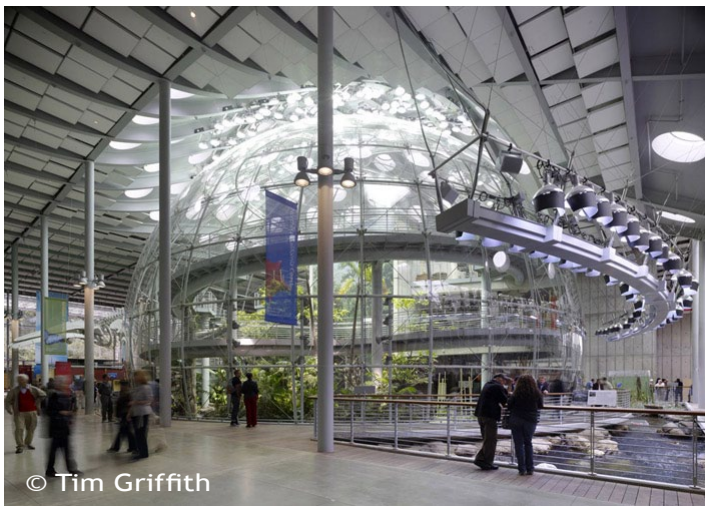
The rolling hills included in the green roof's design were inspired by Piano's witness of San Francisco's hills, & attempted to mimic the their skyline while making the building lay into the park from an aerial view.



© Wired Magazine







Several images displaying the versatility in materiality, form, & style.

images © California Academy of Science

response

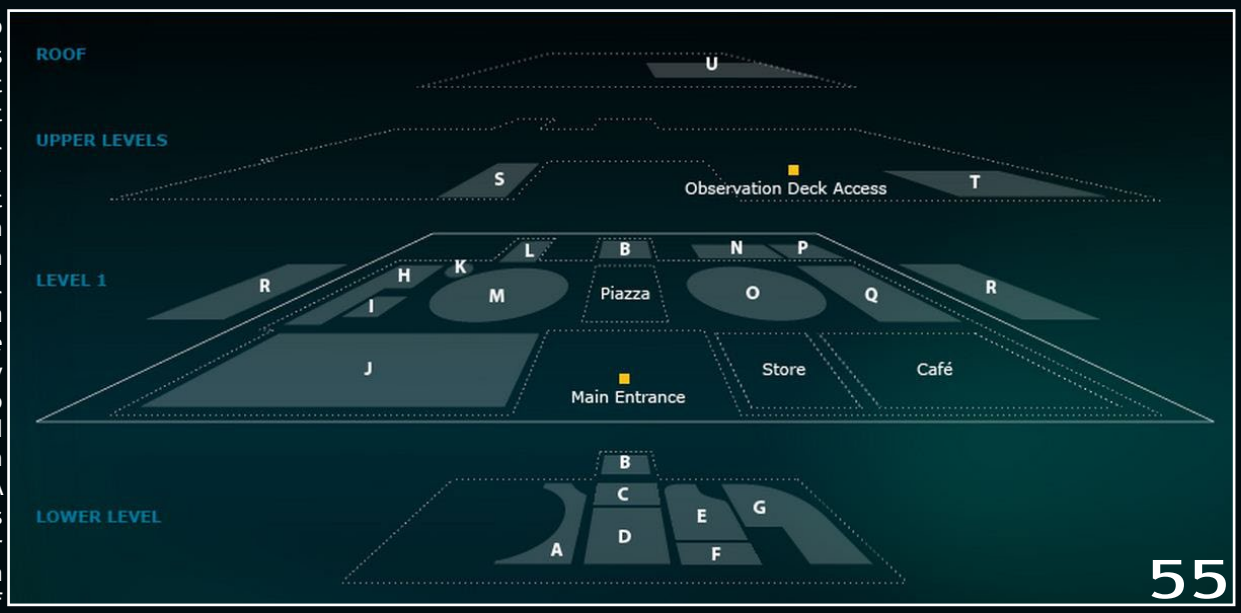
This building displays exemplary sustainable technologies at hand in the world today. The design accommodates for an interesting palette of materials, varying from classically placed recyled concrete to more industrial metal applications. Additionally, the sustainable nature of the building's materiality is remarkably inspiring.

The building design also accommodates qualitative human interaction within the spaces without alienating the individual for participating in buildings with such large-scaled elements.

The voluptuous nature of the green roof provides for ventilation, solar gain, alternative roofing system, ecological maintenance, & certain metaphorical qualities. The exceptional functionality, coupled with ethical & aesthetic value, makes for a model to be looked to when designing sustainable solutions.

However, this project has little limitations when it comes to funding. The building is equipt with every sustainable upgrade available on the market today and uses little to no tact when attempting to find efficient economical solutions.

a. Phillippine Coral Reef
b. Swamp
c. Alligator Cars
d. Water Planet
e. Northern California Coast
f. Discovery Tidepool
g. Amazonian Flooded Rainforest
h. Islands of Evolution
i. Science in Action
j. African Hall
k. Pendulum
l. Early Explorers Cove
m. Planetary
n. Research Lab
o. Rainforests of the World
p. Building Green
q. Climate Change in CA
r. Academy Gardens
s. Naturalist Center
t. Forum
u. Living Roof



local history

Portland is located at the convergence of the Columbia and Willamette Rivers in the valley of Mount Hood. Portland was founded by William Overton & Asa Lovejoy on a canoe trip on the Willamette River. The resources, views, & access were seen to be very fruitful, & so Overton bought the land, started developing, and named the city in 1845, after Portland, Maine.

By 1850, the population of the area had risen to about 800 people, containing a post office, log-cabin hotel, & newspaper. In 1851, Portland was incorporated and therein became the second largest city in the midwest.

In 1859, Oregon became the 33rd state to join the Union, leaving behind its epithet of the Oregon Territory, which stretched from the Rocky Mountains to the Pacific Ocean. Portland then started to grow significantly, creating an economy shipping lumber, fish, wheat & produce all along the western coast, eventually becoming the busiest port north of San Francisco.

Portland's first sewer system was built in 1864, consisting of a simple collector from homes & business which flowed directly into the river. The system grew, & by 1883 the city had 15 miles of terra cotta pipe ranging from 9 to 18 inches in diameter.

Portland then began expanding its access to other parts of the nation with rail lines & improved road conditions, and by the turn of the century Portland had 90,000 residents, the largest metropolis in the Northwest.

By 1905, Portland had 150 electric streetcars operating every hour to accommodate a moving & growing population. The city's streetcar system eventually gained recognition as being one of the most scenic lines in the Northwest, subsequently becoming on of the most efficient streetcar systems on the West Coast, & the third largest in the world (PDXHistory, 2010).

Due to the fact that the city's sewage led directly into the river, evironmental tests were performed in the late 1920's showing that the Willamette River was extrememly polluted. The river was killing fish, was lacking oxygen for organism nutrients, & was spreading disease & bacteria.

In 1952 the city opened a waste water plant, discharging treated water into the Columbia River, resulting in significant improvements in the Willamette's water quality. Progress continued, resulting in stricter pollution laws laid out by Oregon Govenor Tom McCall in 1967, the Clean Water Act of 1972, and attempting to control combined sewer overflows in 1991 (City of Portland, 2010).

transit history

Portland's first ferry opened in 1953 which crossed the Willamette River at Stark Street, located on the southern side of downtown. Transit began to regionally expand in 1968 when the Oregon Central Railroad construction broke ground, peaking between 1872-1884.

Portland began development on both sides of the river in 1887 with the construction of the Morrison bridge, the first bridge to cross the Willamette River. From this point on, the city began developing at a faster rate. In 1890, the city's first electric car was opened, leading to further development of the downtown area. In the early 1900's, the city's regional transportation expanded with the Portland-Seattle railroad completion (Portland Bureau of Transportation, 2010).

The city then began expanding quickly with the building of nine bridges throughout the next twenty years, as well as airport & highway construction through the 40's & 50's. With the growth of the personal automobile, the city experienced a decline in rail usage, resulting in the closing of the streetcar as well as the suspension of the Interurban rail service between Oregon City and Portland.

This decline in public transit turned around in 1969 with the creation of TriMet, the Tri-County Metropolitan Transportation District of Oregon. In 1971 TriMet designed a 1990 Master Plan, completed in 1973 along with the city's first bike plan. Several acts were passed in regional & local governments to aid the funding for transit programs, including the Senate Bill 100 adopted by the Oregon Legislature establishing land-use laws to protect livability and prevent sprawl(TriMet, 2011).

In 1975, TriMet launched 'Fareless Square', a district within the downtown area with free transit. Two years later the downtown Transit Mall opened, completing the strategy to increase transit use while resulting in reduced air pollution (TriMet, 2011). The city's transit continued to expand with the introduction of the eastside Banfield Light Rail Project, the city's first MAX line, in 1980.

The city's trolley systems were re-introduced in 1987 following the 1986 two-million-dollar grant from the Urban Mass Transportation Administration to enable the purchasing of vintage trolleys (TriMet, 2011). Within the past two decades, the city has worked on expanding its transit lines throughout the entire metro area.

goals of thesis

My goals in directing this thesis consist of pushing my learning in a direction of my own desire: the philosophical questioning of the determined life-cycles of buildings.

As buildings age, they become less efficient and the intended inhabiting population change, creating the opportunity for the building to sink from its functionality as well. As material production becomes more & more of an issue pertaining to resources, pollution, & disposal, there is a larger need for an investigation into how to curb these environmental devastations to finally begin to work towards a better future.

Previous generations apologize to us about how they failed in their attemps to preserve our futures. However, I would argue the it is not simply the failure of the baby boomer generation which is causing this ecological armageddon. Rather, it is the fact that the following generations did not pick up the baton that the boomers were attempting to hand off.

Our culture has been riddled with terribly manufactured items of unhealthy ingredients & materials filling our landfills, making our children obese, while creating cancers with every new technology that we make affordable.

It is in this mindset that people have begun to view the 'right' purchase as the cheap purchase, consuming large amounts of materials, polluting during their productions, and breaking immediately following their disposal into a landfill or incinerator.

It is because of this mentality that there is no longer a desire to think of purchases as investments. Society no longer knows what credit & equity mean. We no longer have the foresight to think for the future, to save (money, resources), to enrich (our communities, our environment), to progress.

This is why I believe that this thesis investigation is so important, because even if society isn't pushing towards it, they need it. They need a solution.

Designing for buildings that have the ability to morph into further accommodations will solve a significant amount of these problems caused by modern society. It is time that we picked up the baton and trudged forward despite all of the ignorant nay-sayers rejecting scientific facts of diminishing resources and increased pollution.

In this investigation lays to the possibility to expand an up-and-coming design philosophy of designing for the future, without committing to things that will inevitably fail & lose their functionality.

site analysis

qualitative

The site is situated around buildings of five stories and higher, and is currently used a public paid parking. The site exists on one square block, located south of SW Washington and east of SW 10th Avenue. Currently, there are significant amounts of street vendors along the western, southern, & eastern sides, creating a dynamic environment full of pedestrians & workers all day long. The site is located in downtown Portland, surrounded by masonry & concrete structures, with viewpoints of more modern high rises that use sustainable technologies (see next page).

qualitative analysis

The following images depict each intersection of the site. The first row of images, moving left to right, consist of northwest corner of the site [looking west], the building facade on the northern side of the side [looking north], and the view from the side to O'Bryant Square, a public park located across from the northeast corner of the site [looking northeast].

The middle row of images show the western side of the site [looking south], the site [looking east northeast], & the eastern context of the site [looking east].

The lower row shows the southern border of the site, beginning the southwestern corner of the site [looking west], the southern border of the site [looking east] & the southeast corner of the site [looking north].

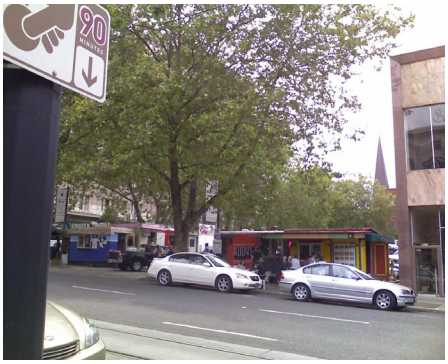
The site contains several mature trees along the perimeter, and maintains a slight natural slope. The majority of the surrounding buildings are quite traditional, however, the northeast corner of the site (top left image) shows more contemporary designs, & even rooftop wind turbines in the distance. The vendors on the site's perimeter would also allow for a less traditional development, presenting the opportunity for a central, cultural & sustainable design of the building for the Institute of Sustainable Solutions.

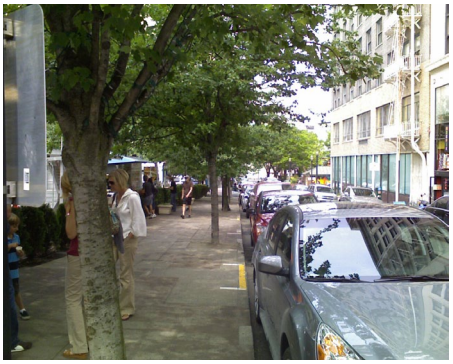
site analysis

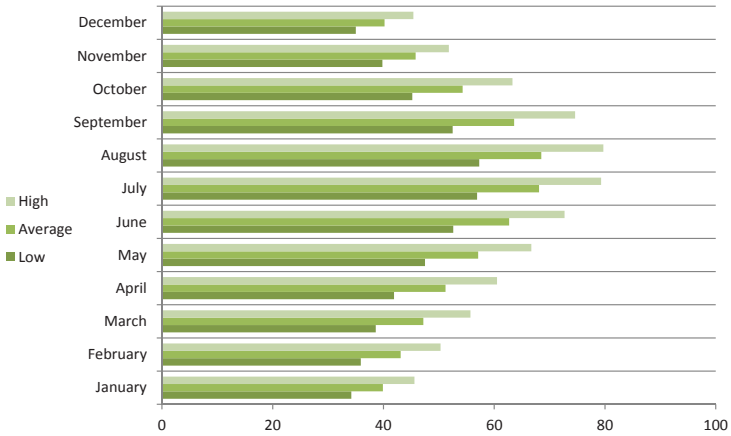




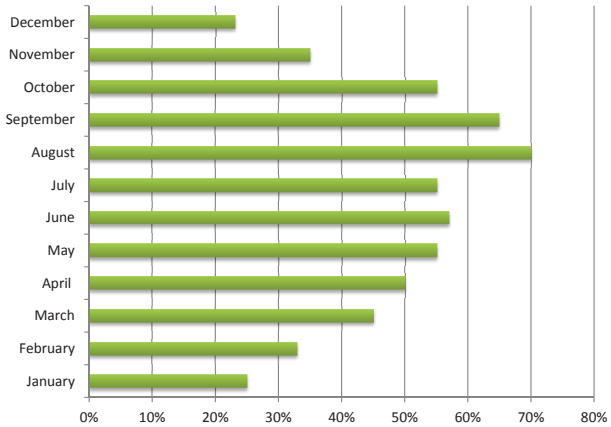




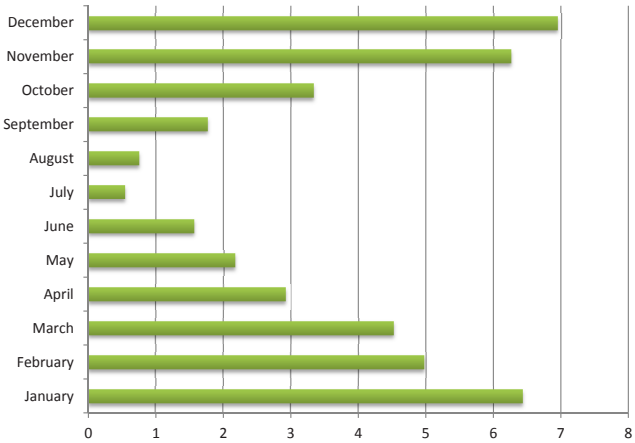




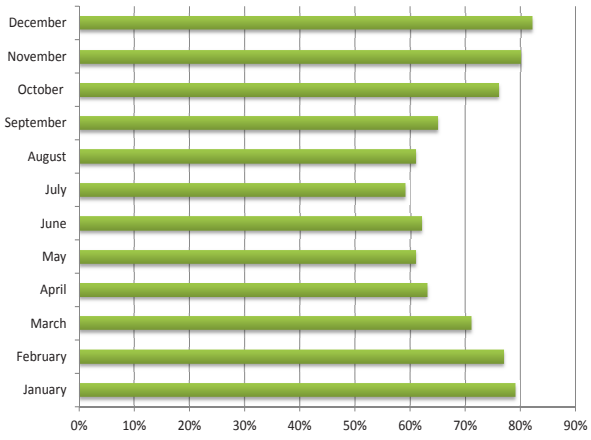
temperature (°F)



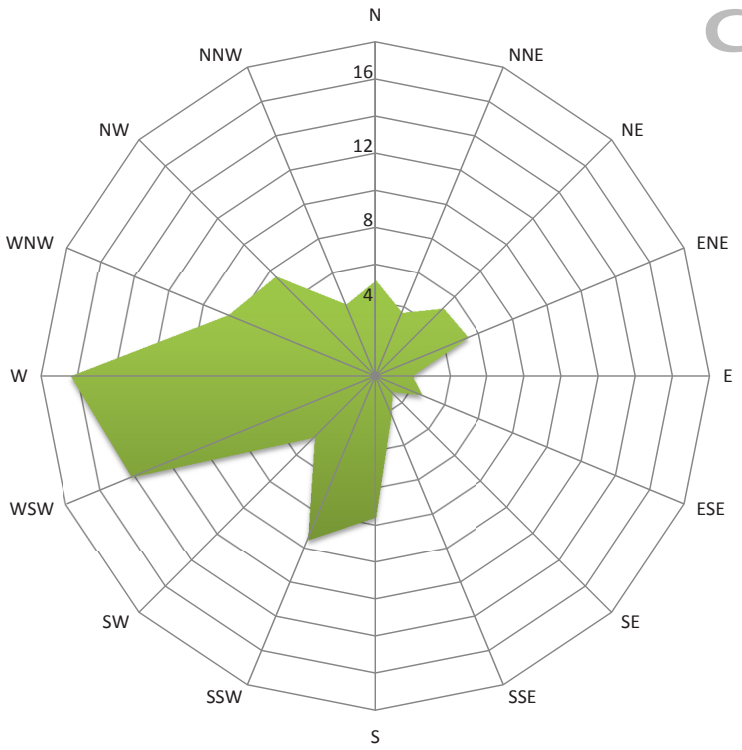
daylight (%/day)



precipitation (in.)



humidity



wind rose

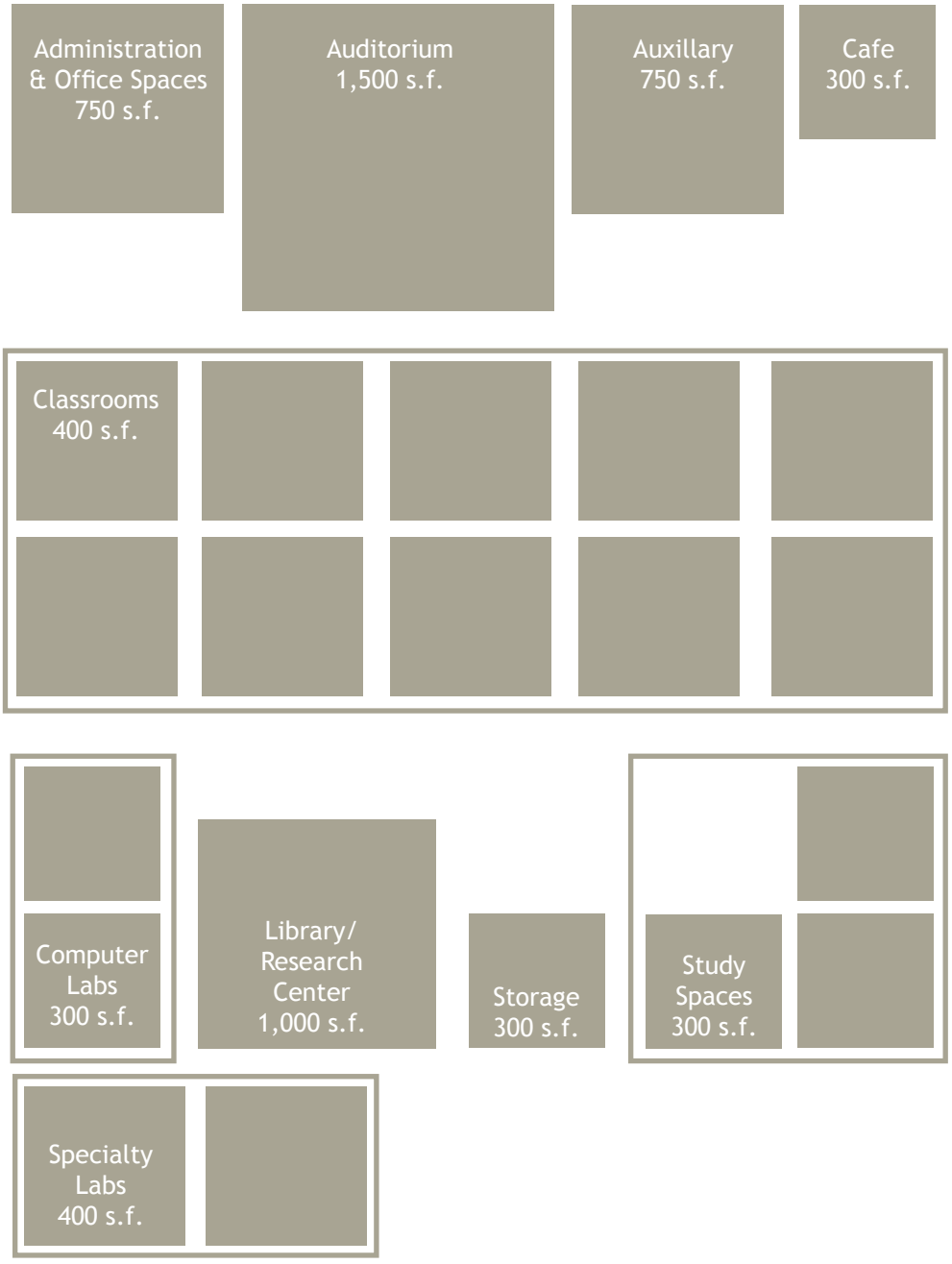
quantitative

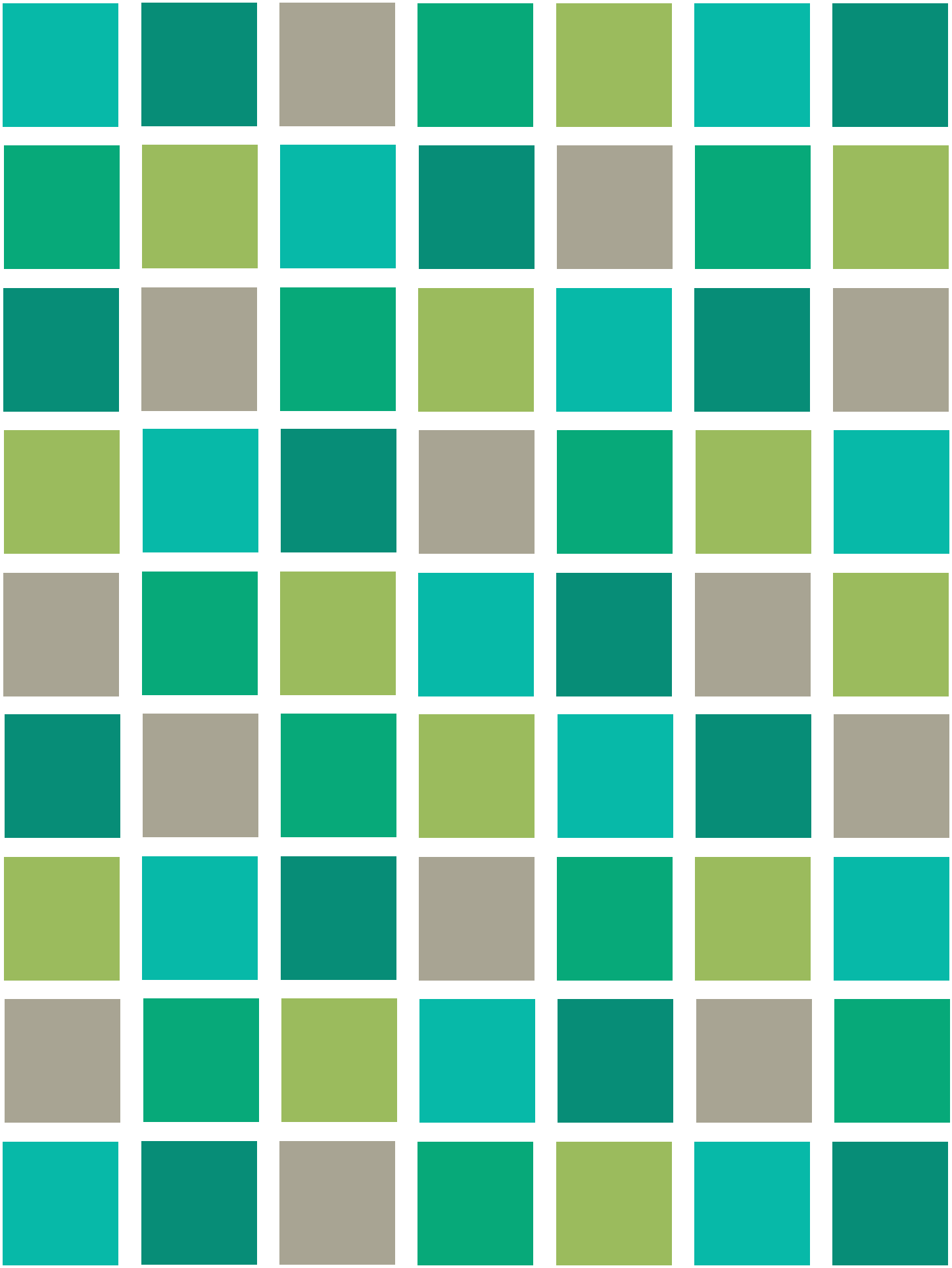
Portland is located within a somewhat temperate climate, having mild summers & winters compared to the rest of the nation. The summers rarely exceed 80ºF, while the winters rarely drop below 30ºF.

The winters contain minimal daylight, as much as 25% can be expected of daytime hours. However, this is also connected to a very rainy winter, as Portland receives minimal amounts of snow.

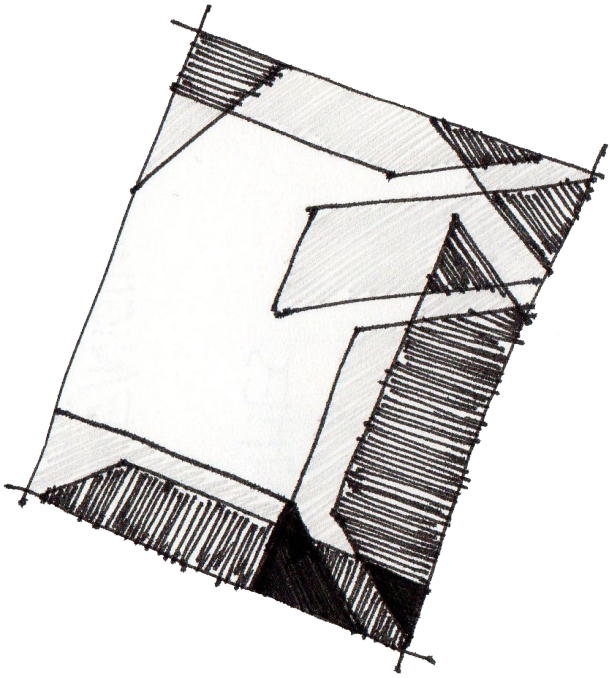
The humidity is quite high, sinking to around 60% during the summer, its annual low. However in perspective of the city's rainy season, this is all to be expected.

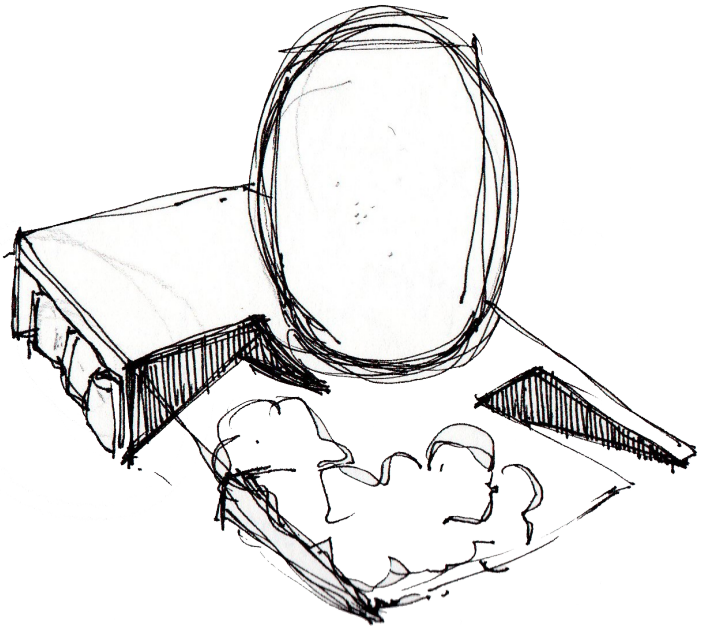
programmatic requirements



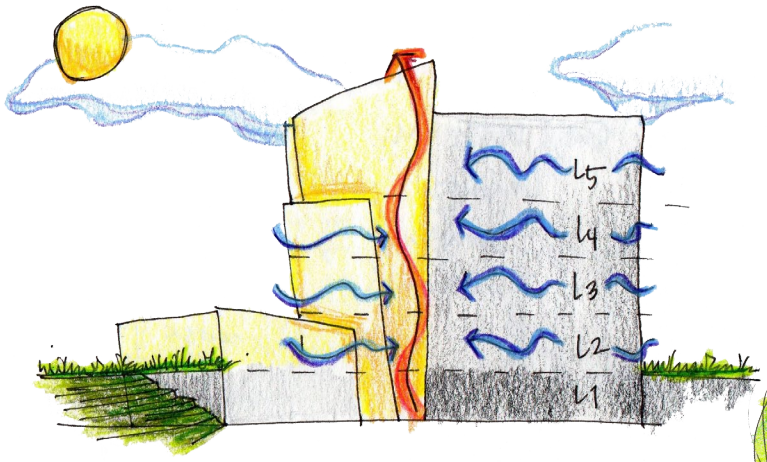


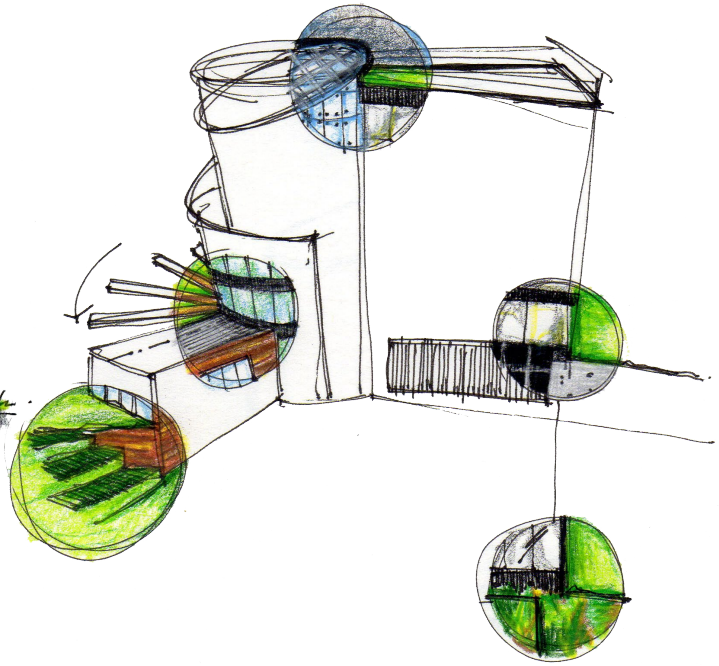
4 process





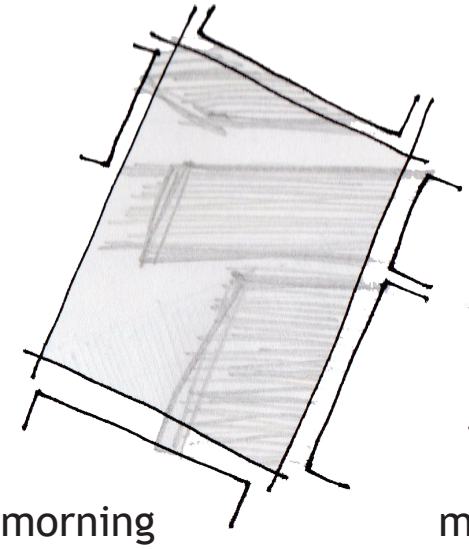
design process



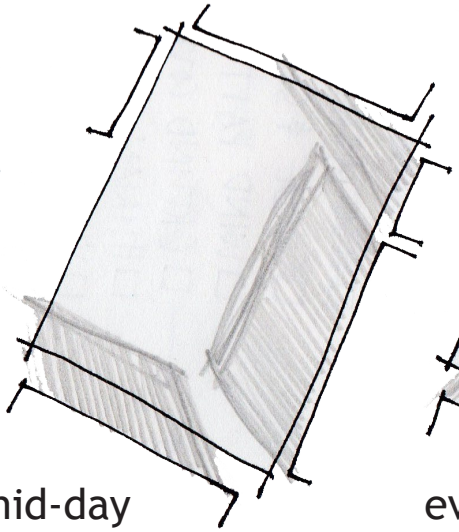


site amenities

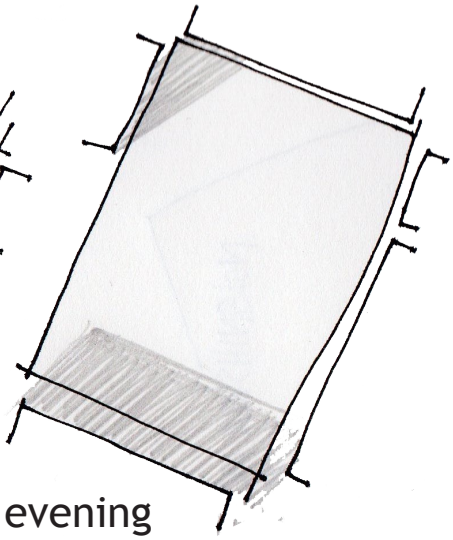
site daylighting



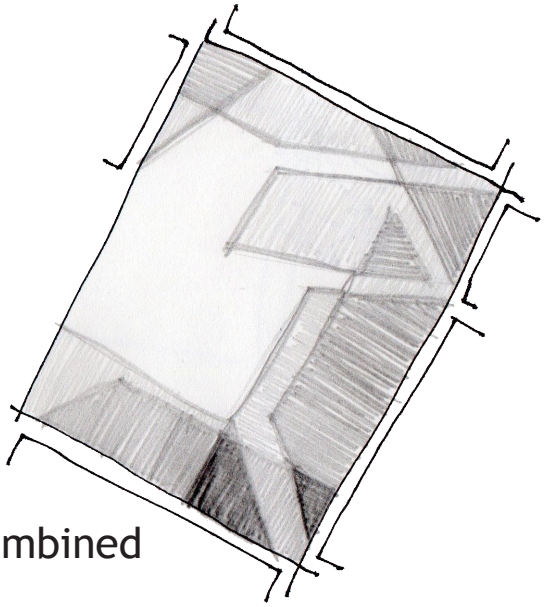
morning



mid-day

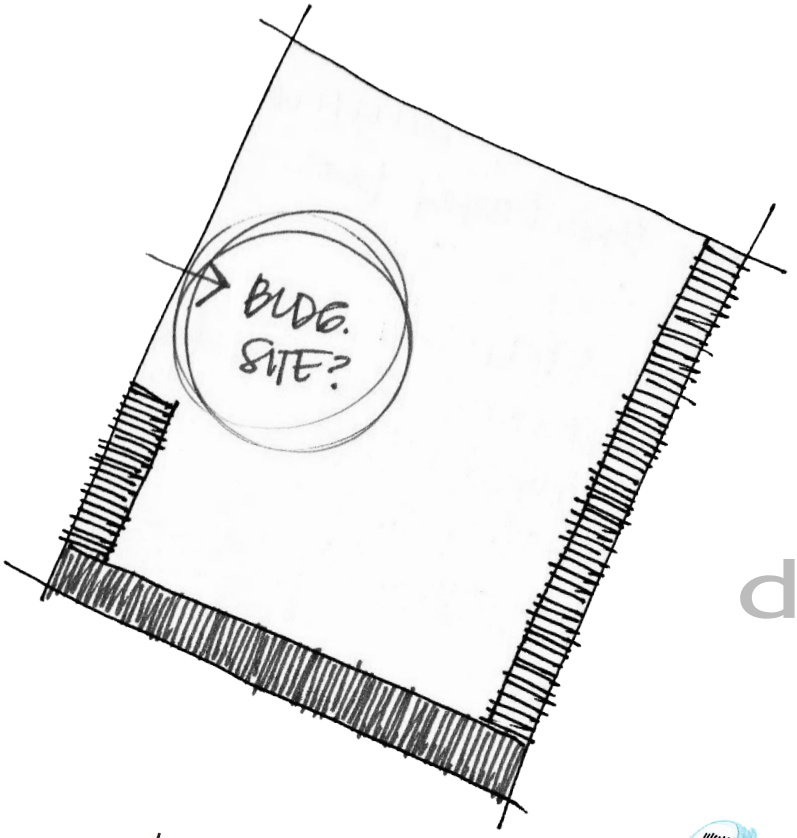


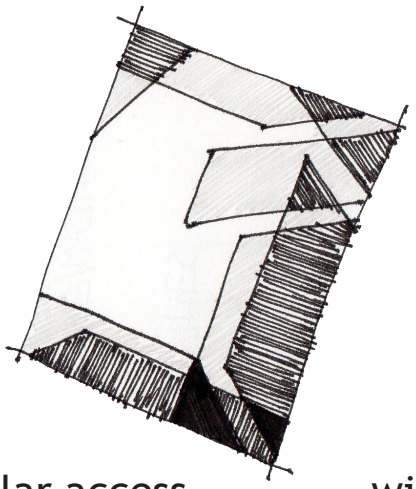
evening



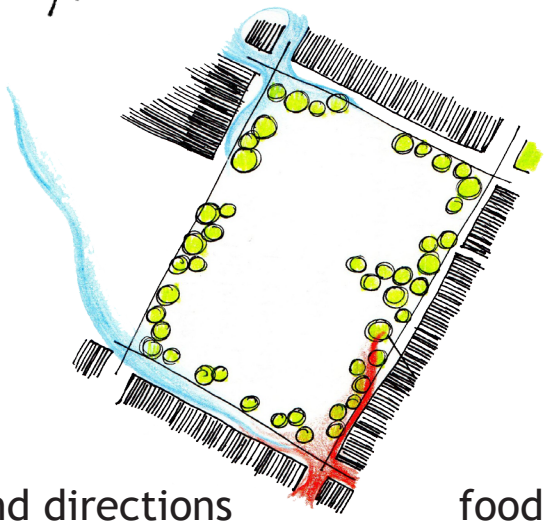
combined

site development





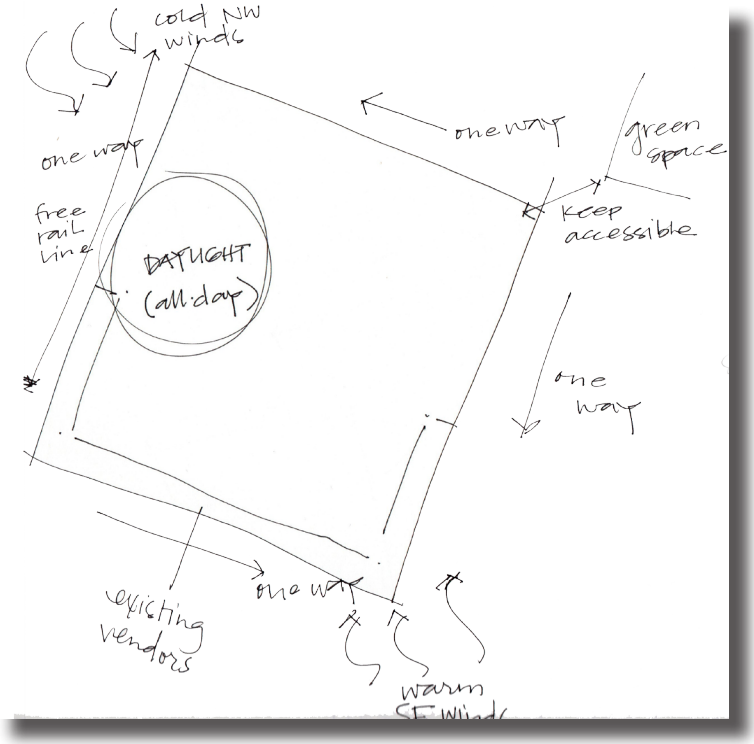
solar access

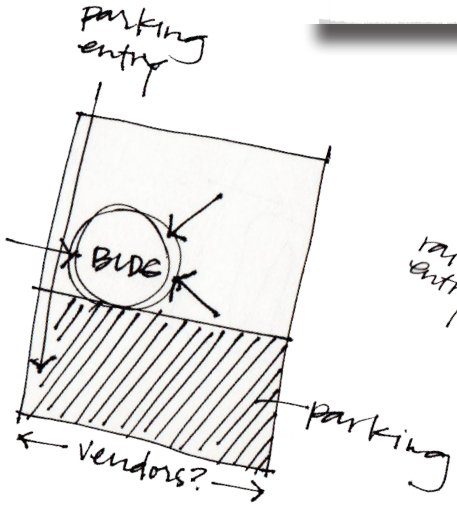


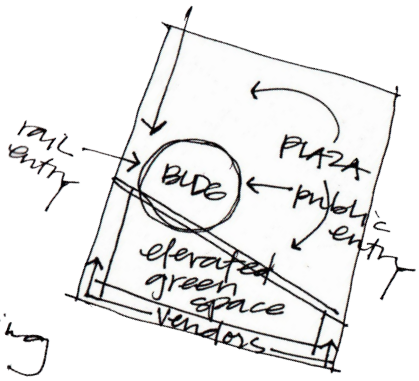
wind directions

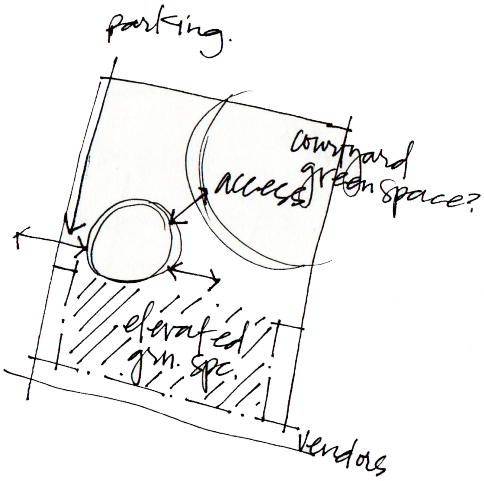
food vendors

design process

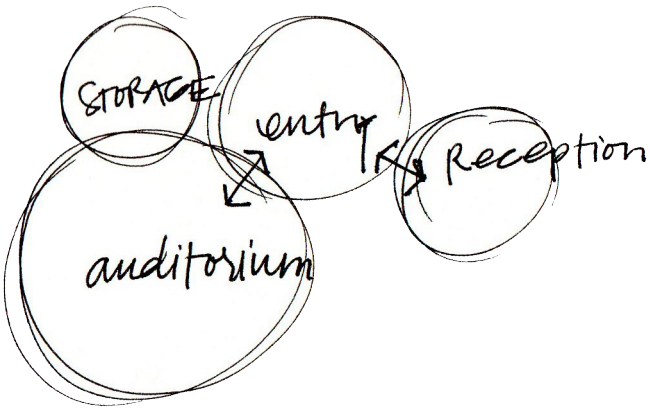


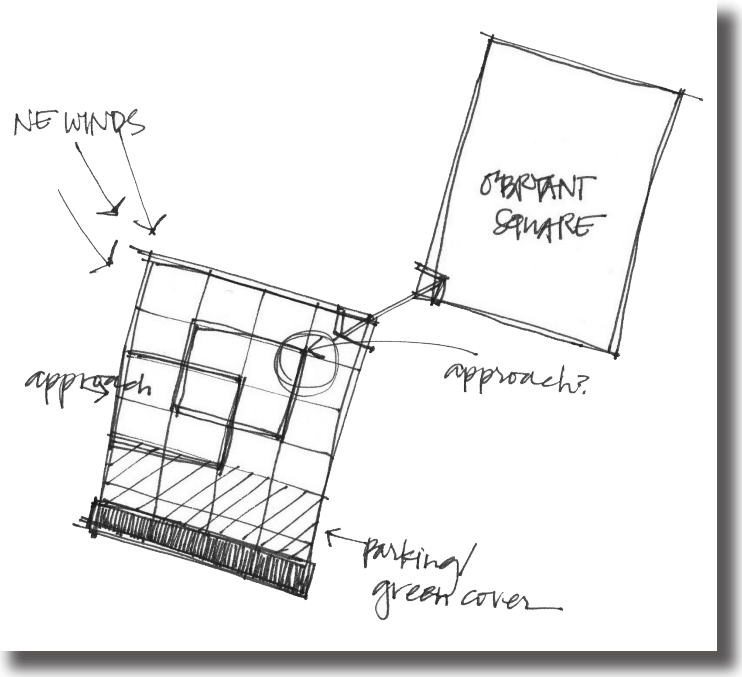


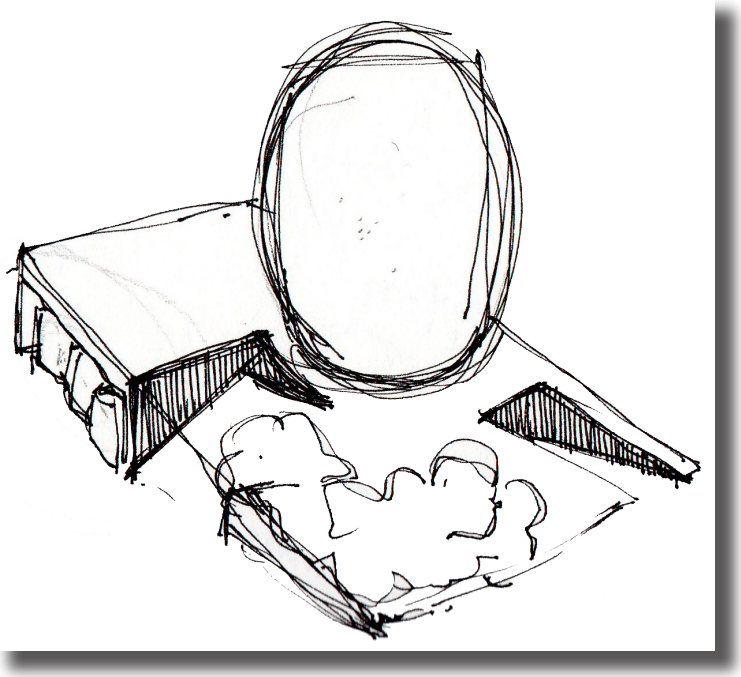




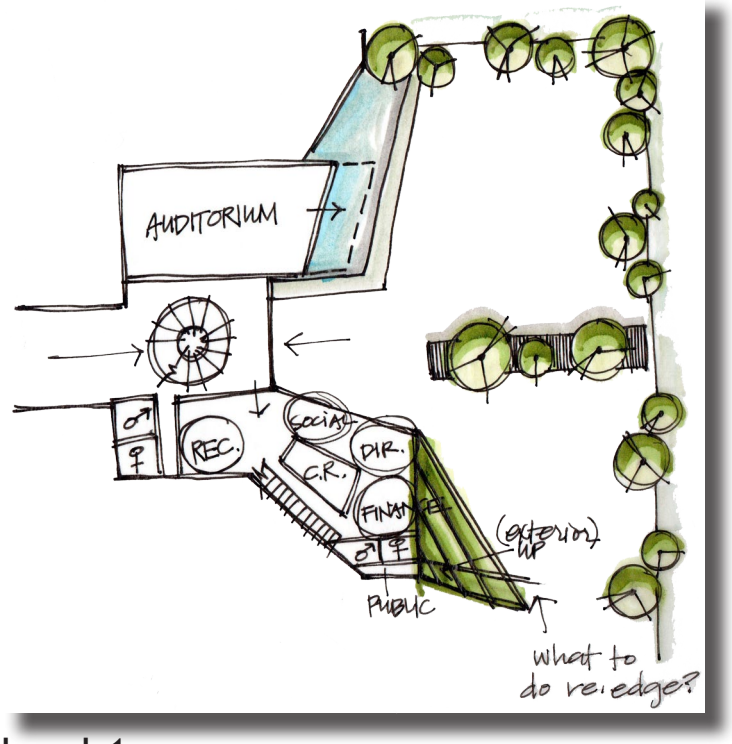
site development

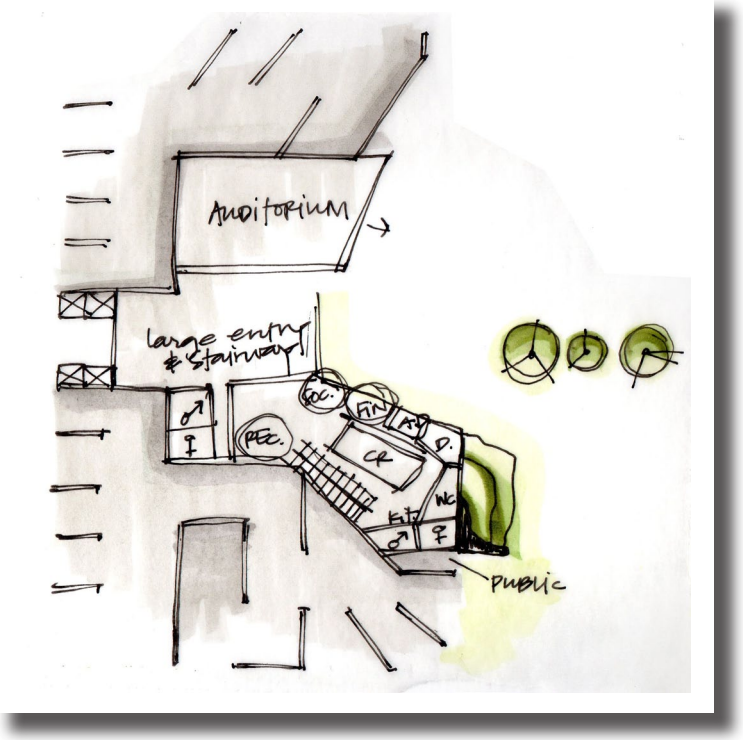






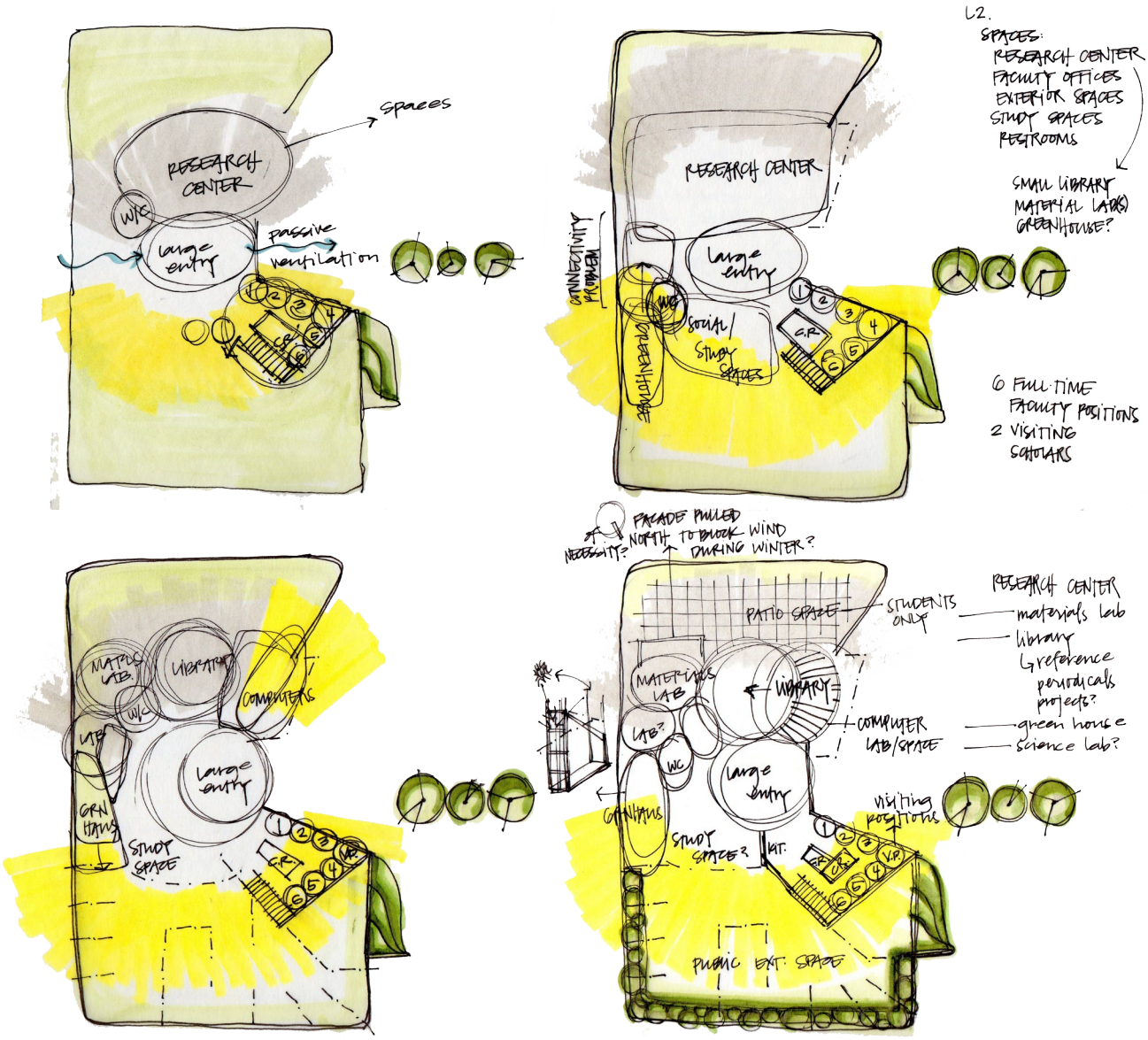
spatial development





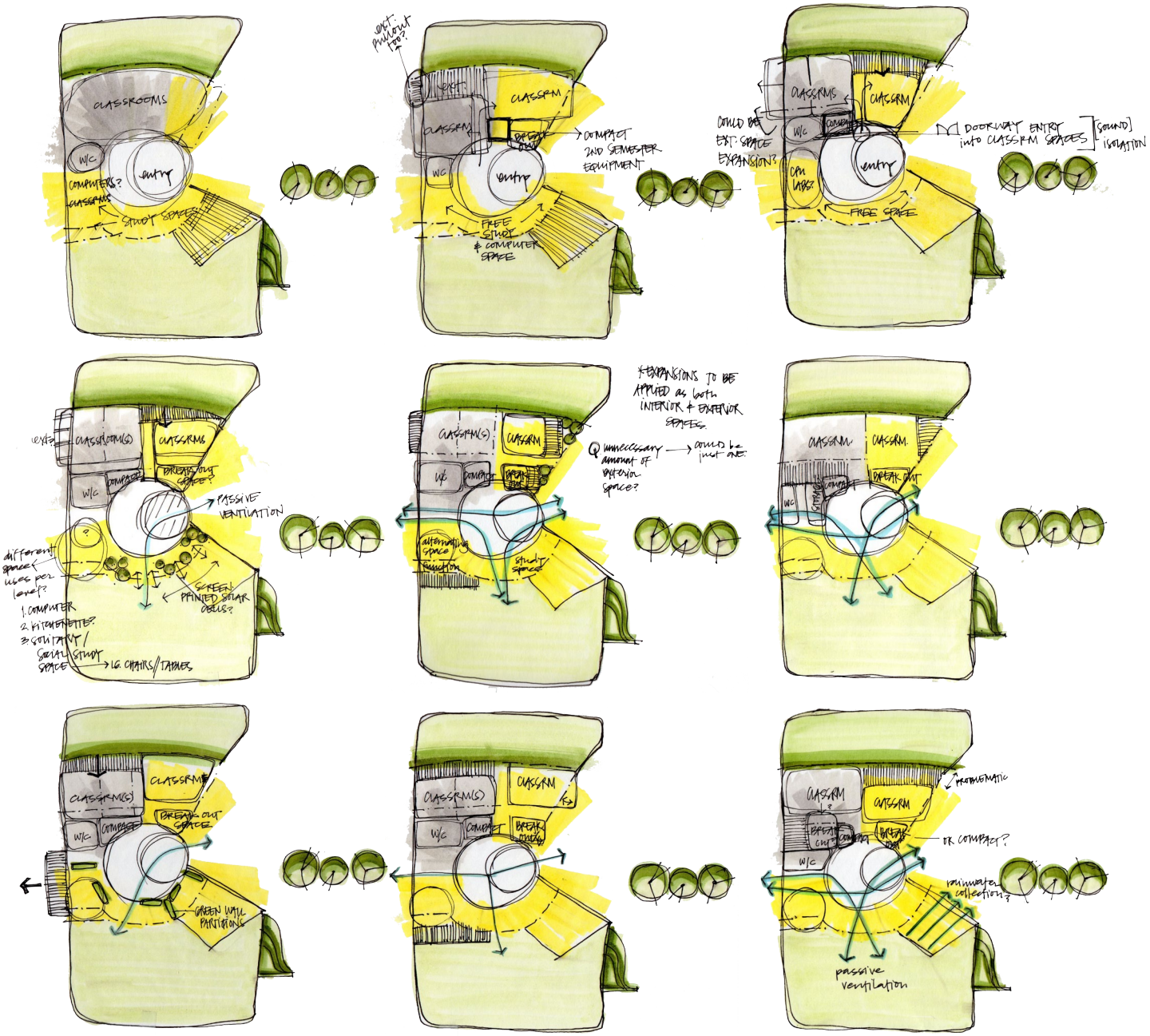
level 1

spatial development



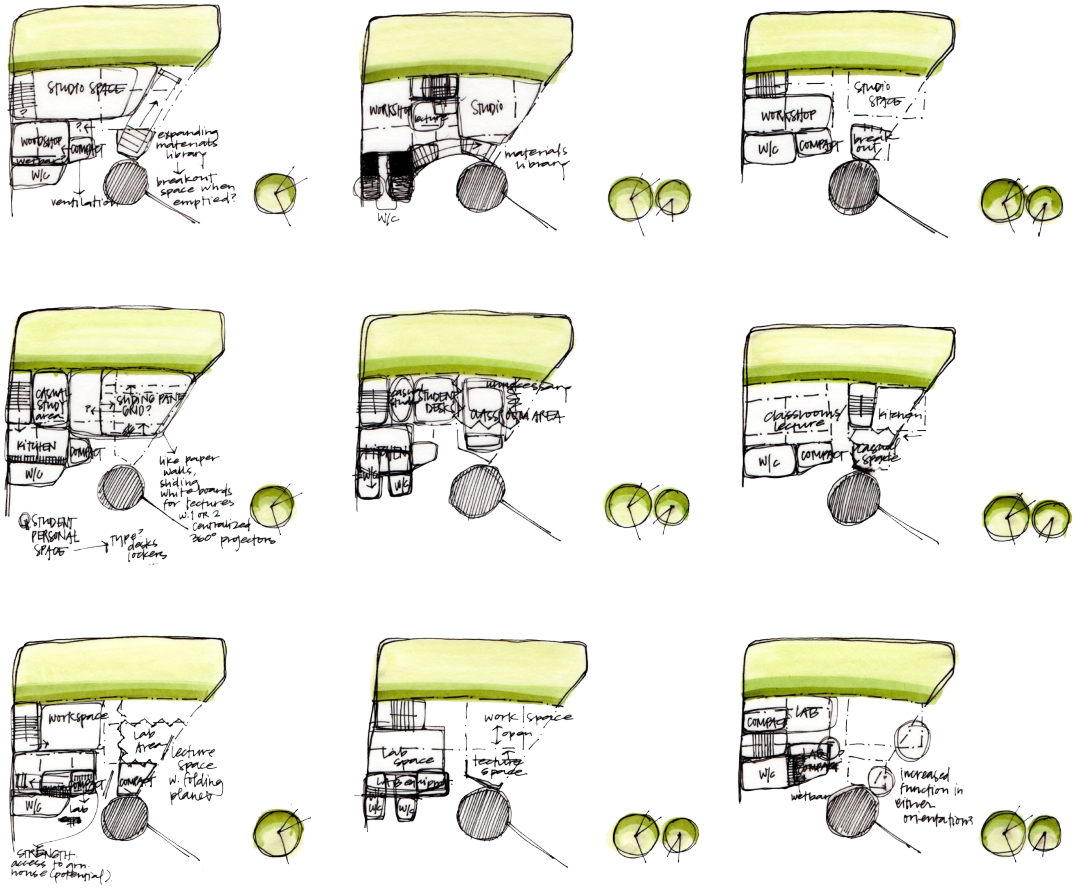
level 2

design process

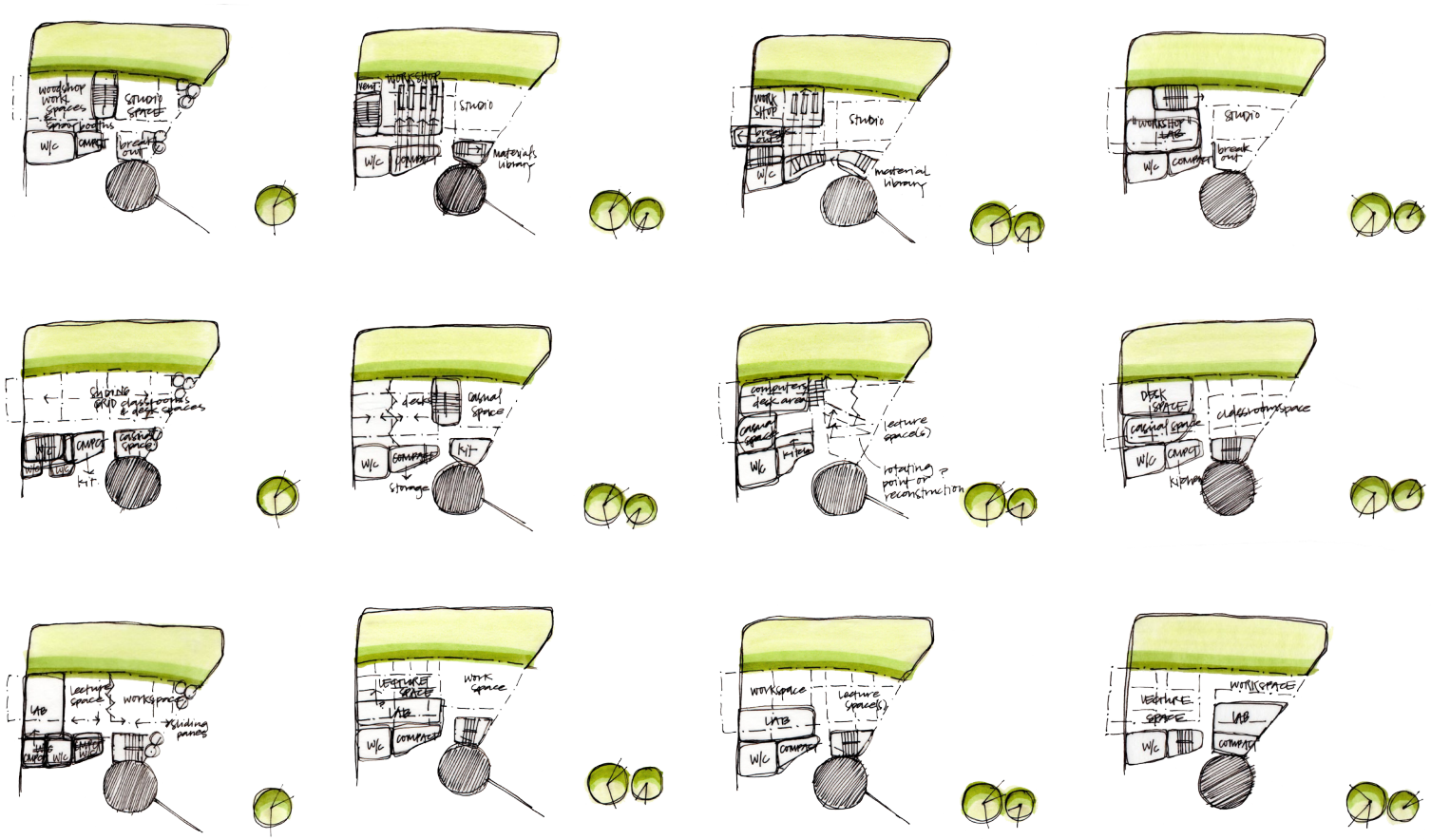


level 3

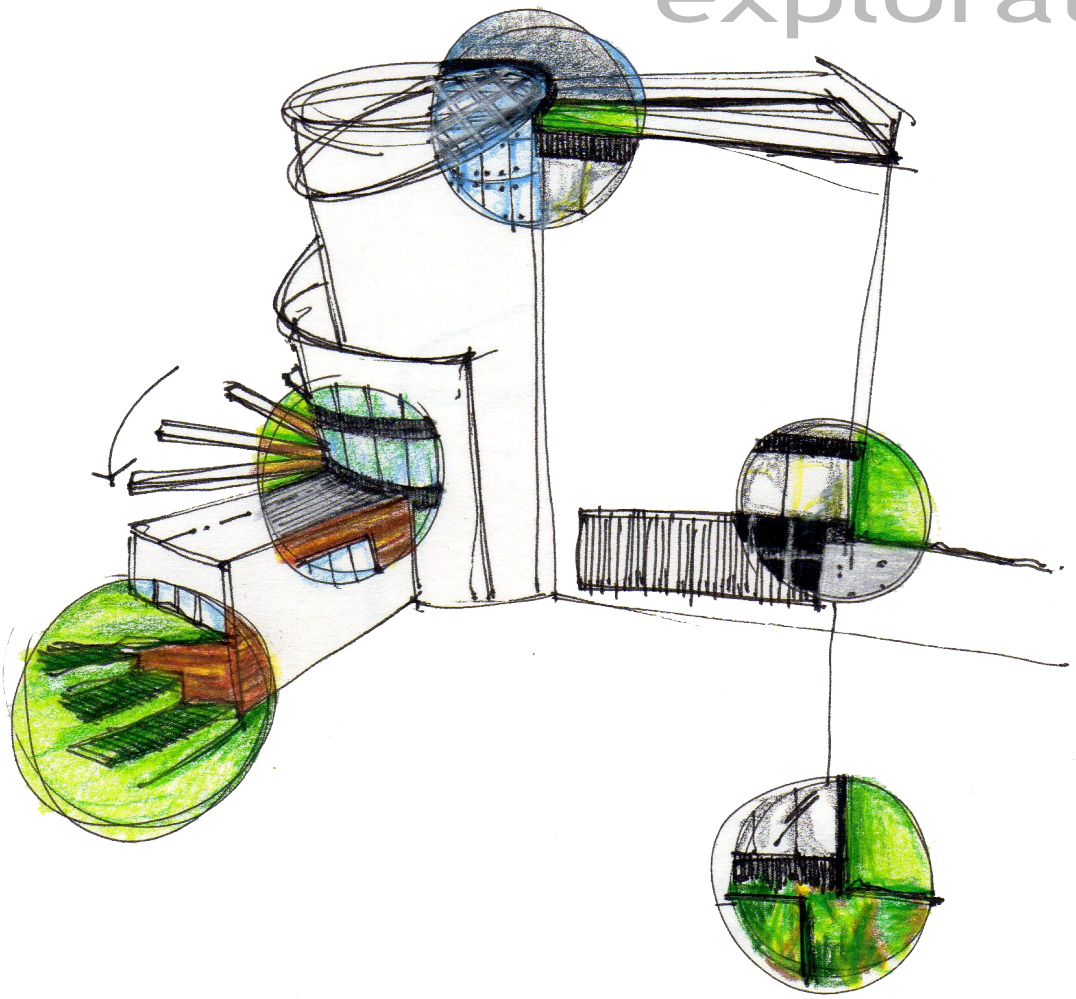
spatial development



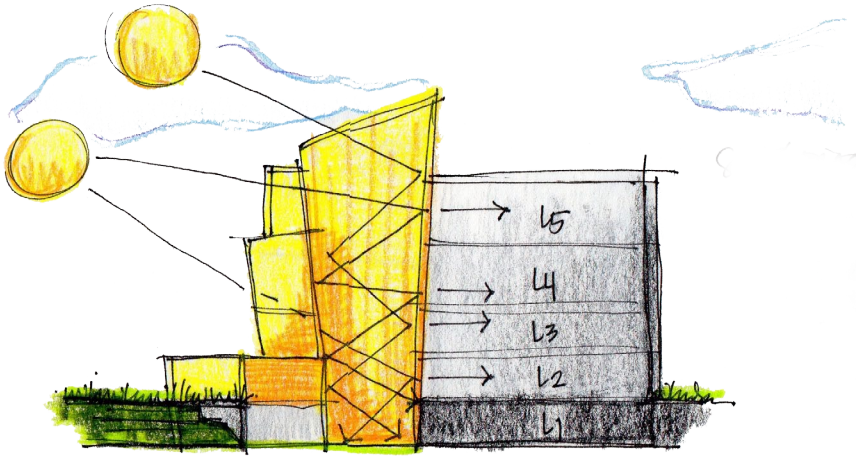
design process

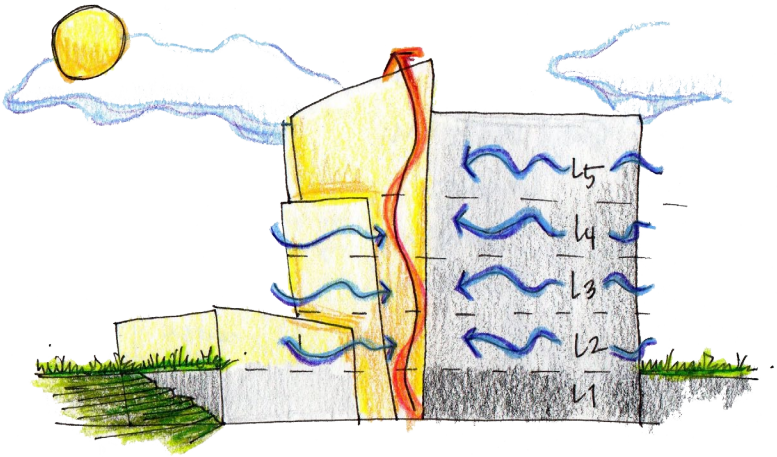


material & climate exploration

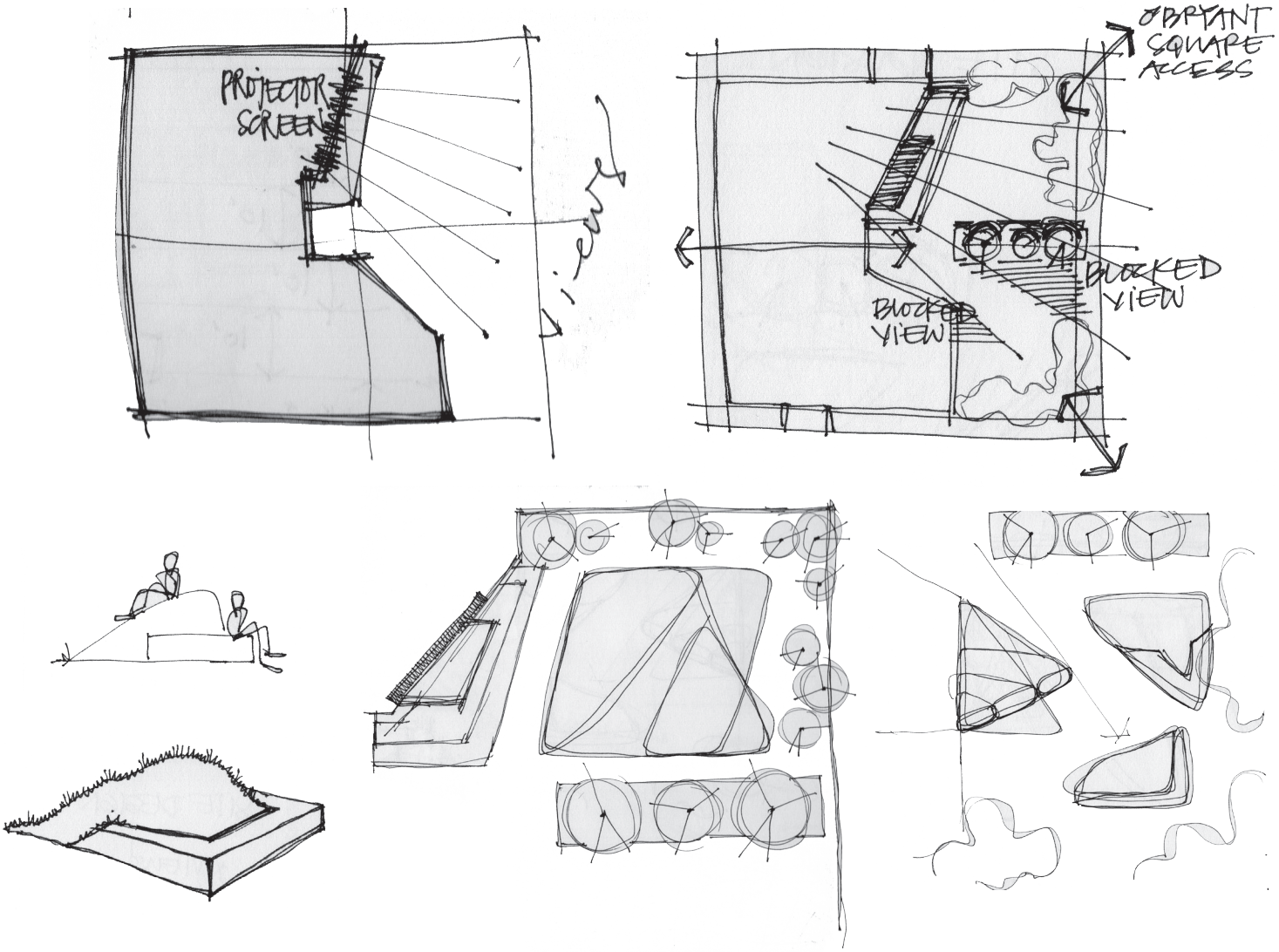


design process

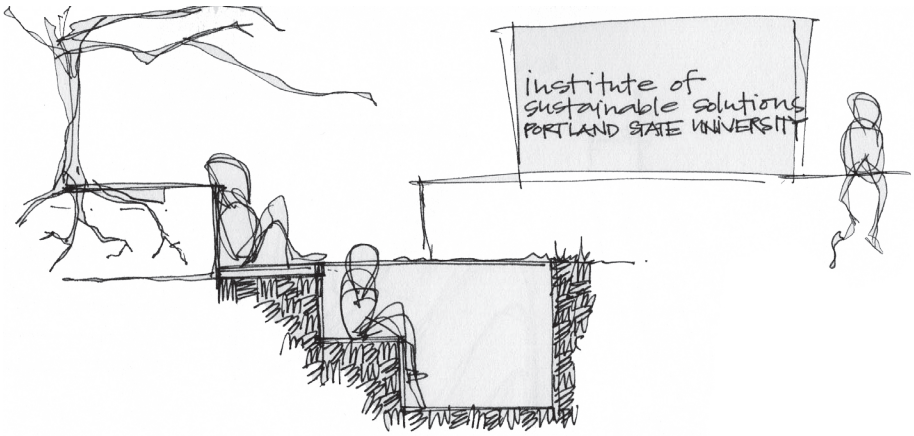


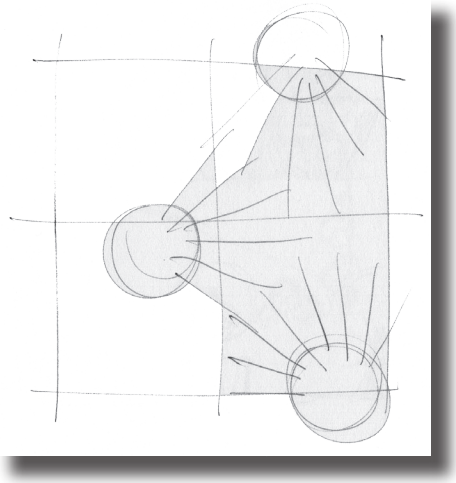


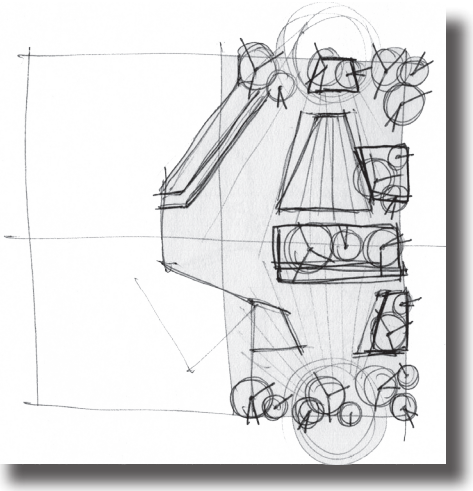
plaza design

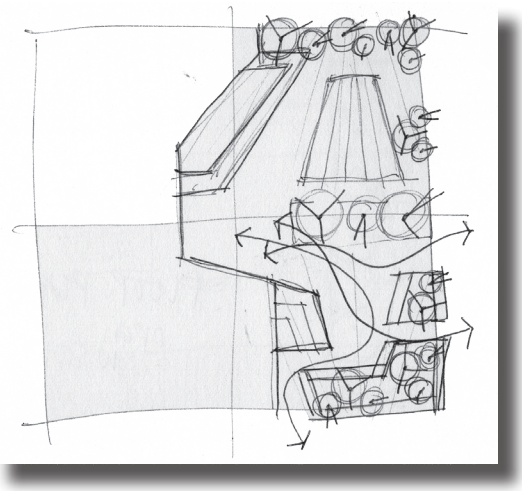


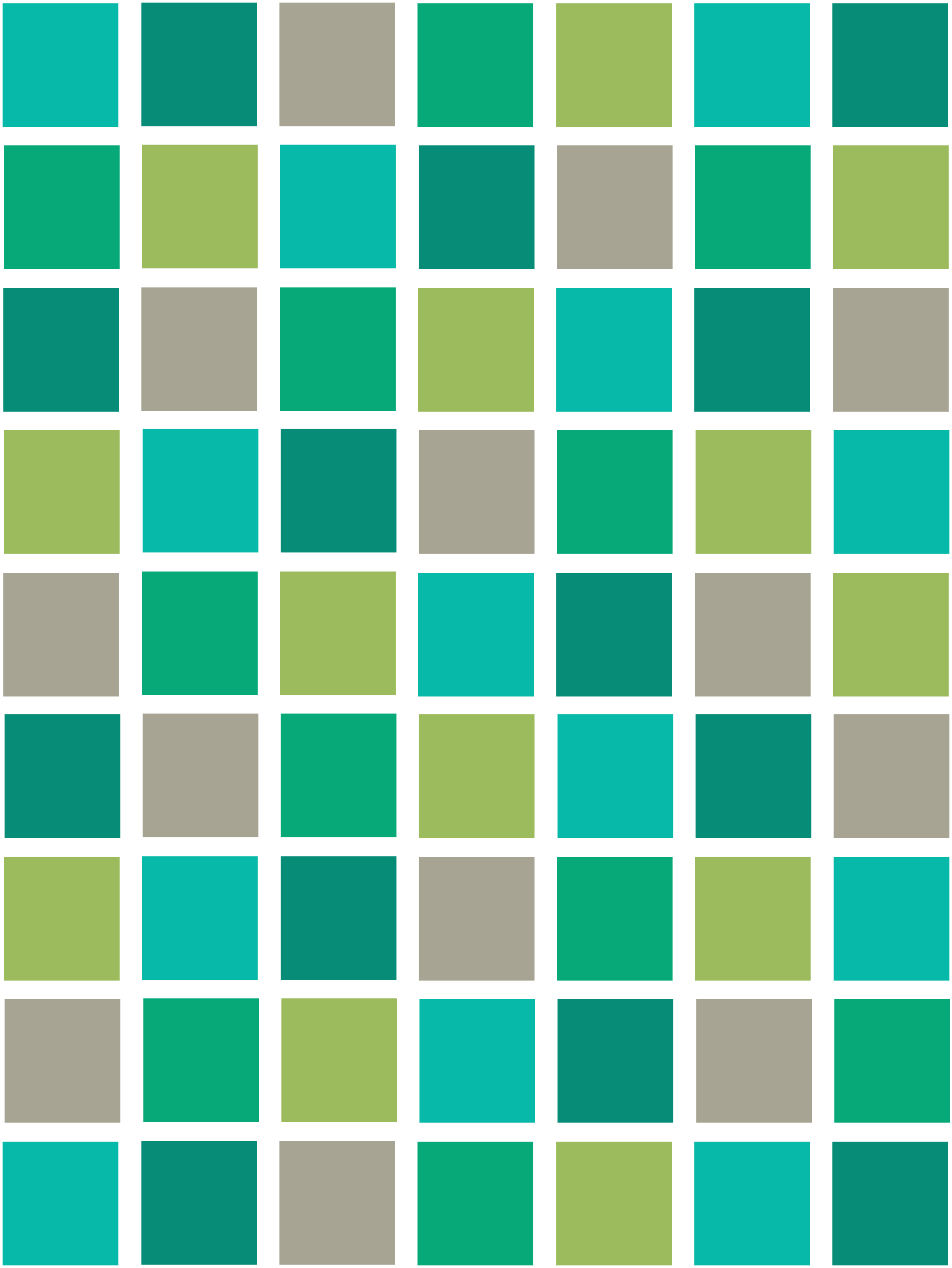
design process





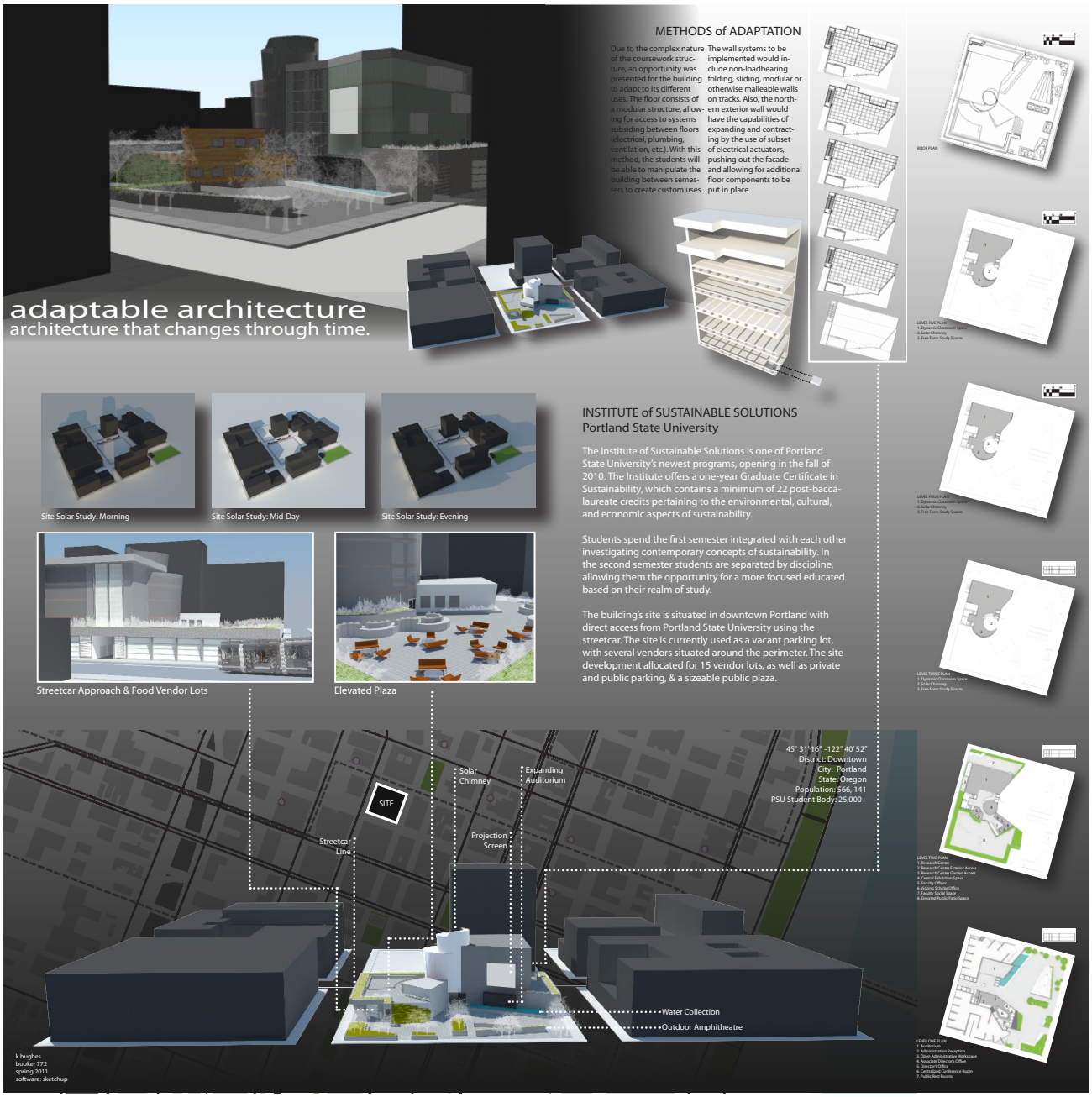






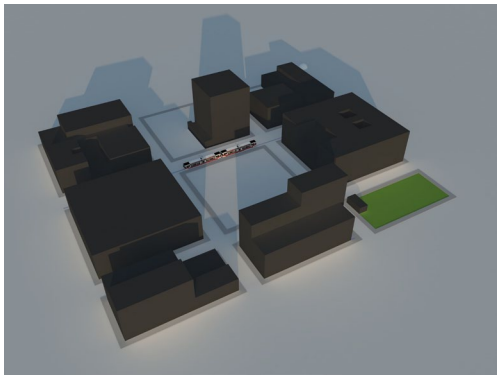
5 design

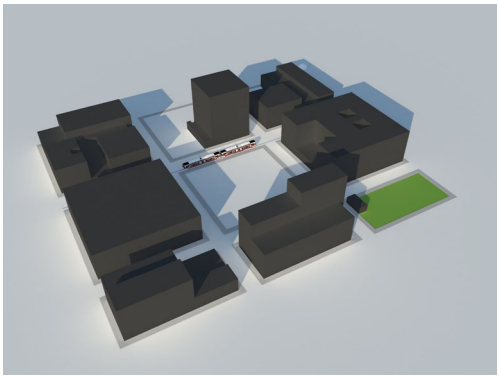
final design

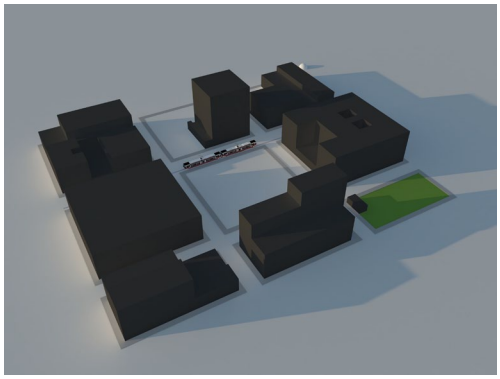


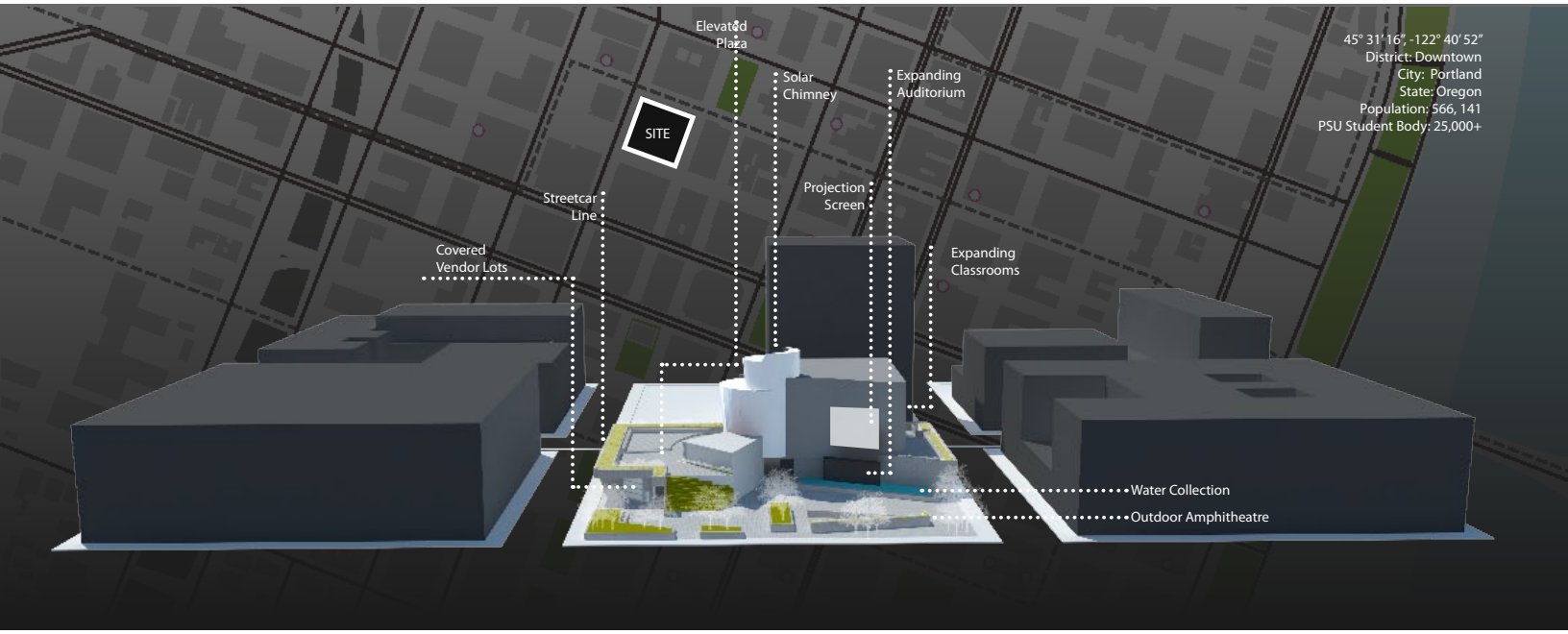
board layout

site daylighting

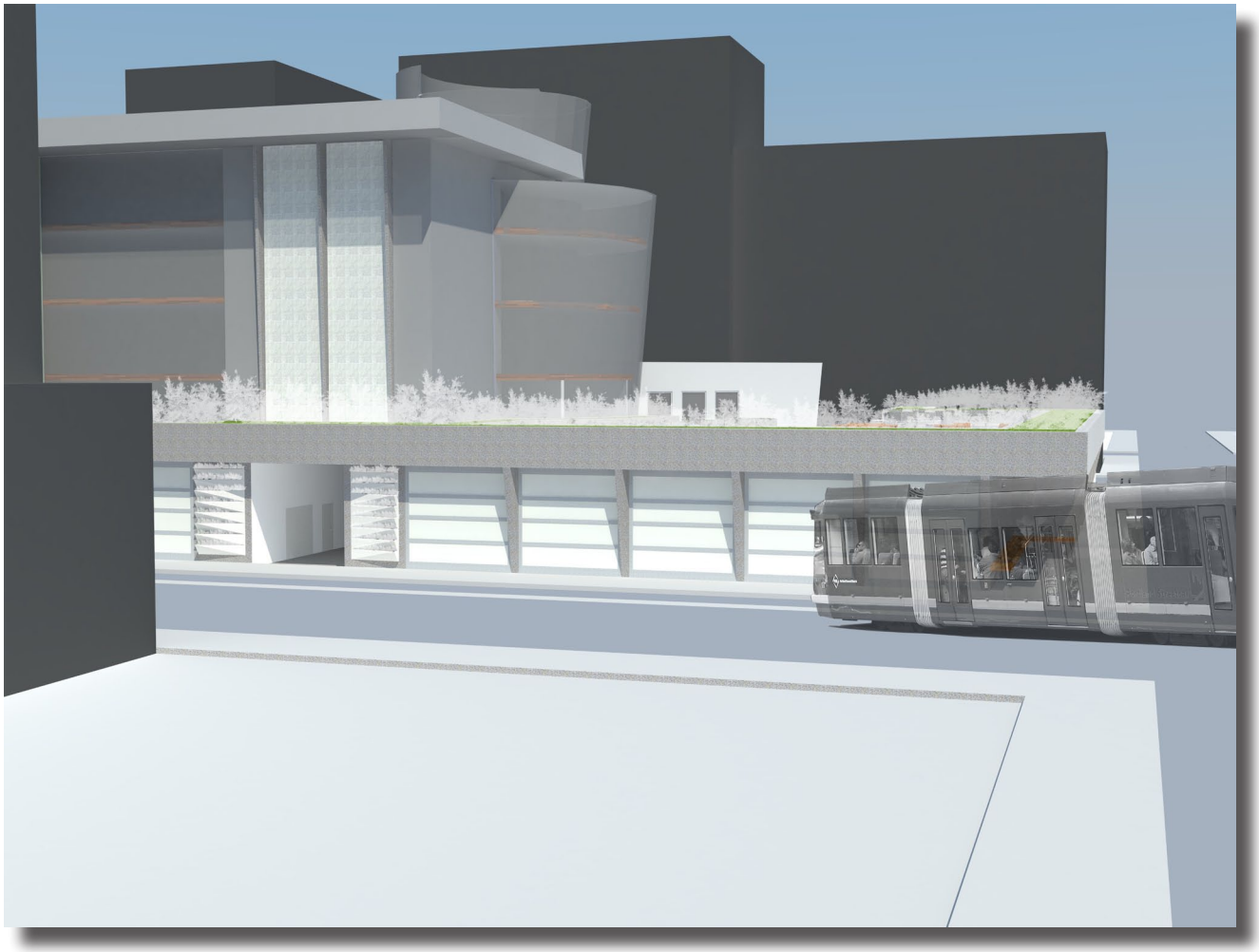






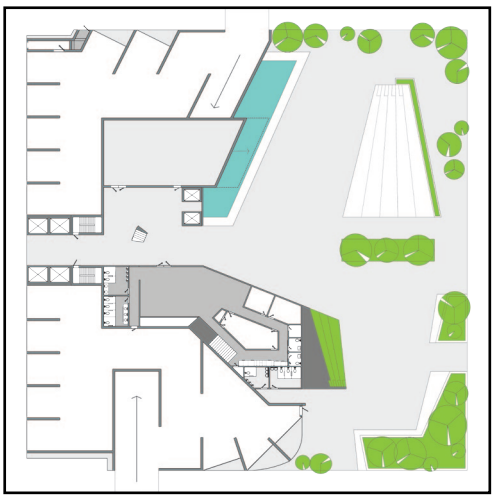


final design

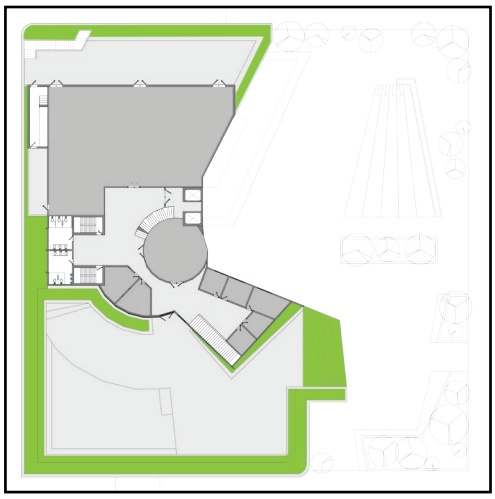


vendor accommodation

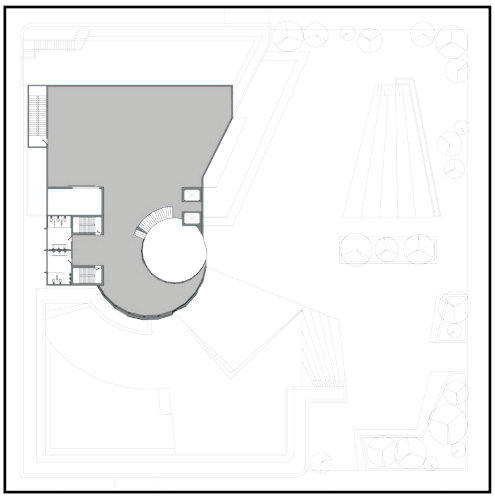
floor plans



level 1

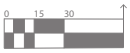


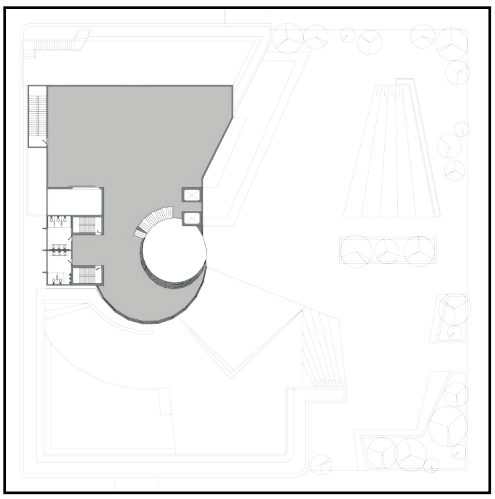
level 2



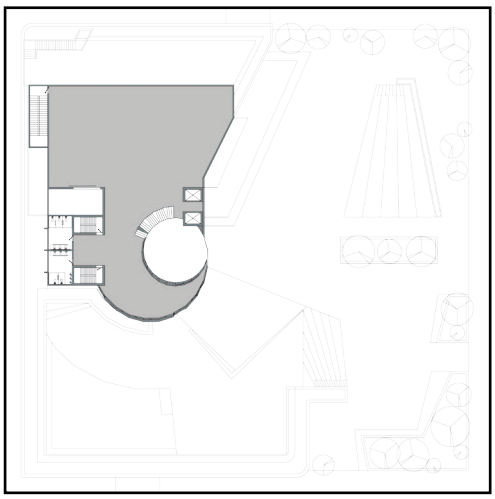
level 3

final design

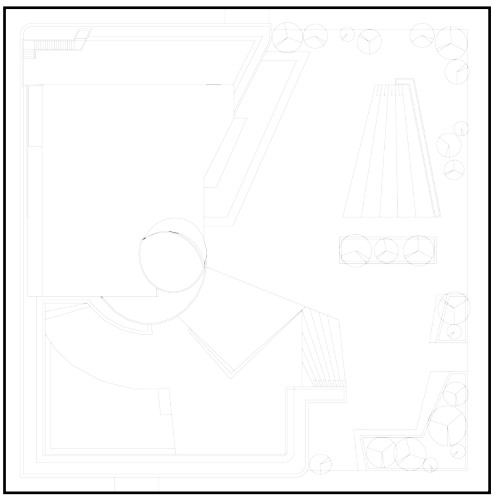




level 4



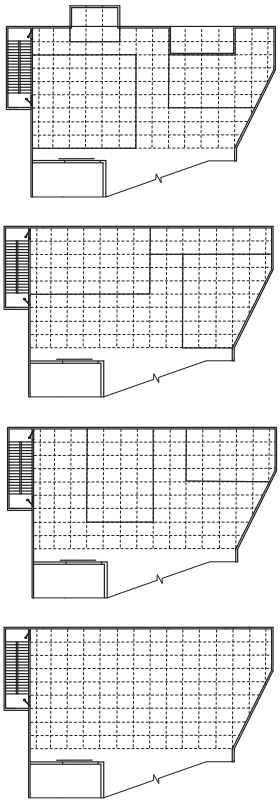
level 5



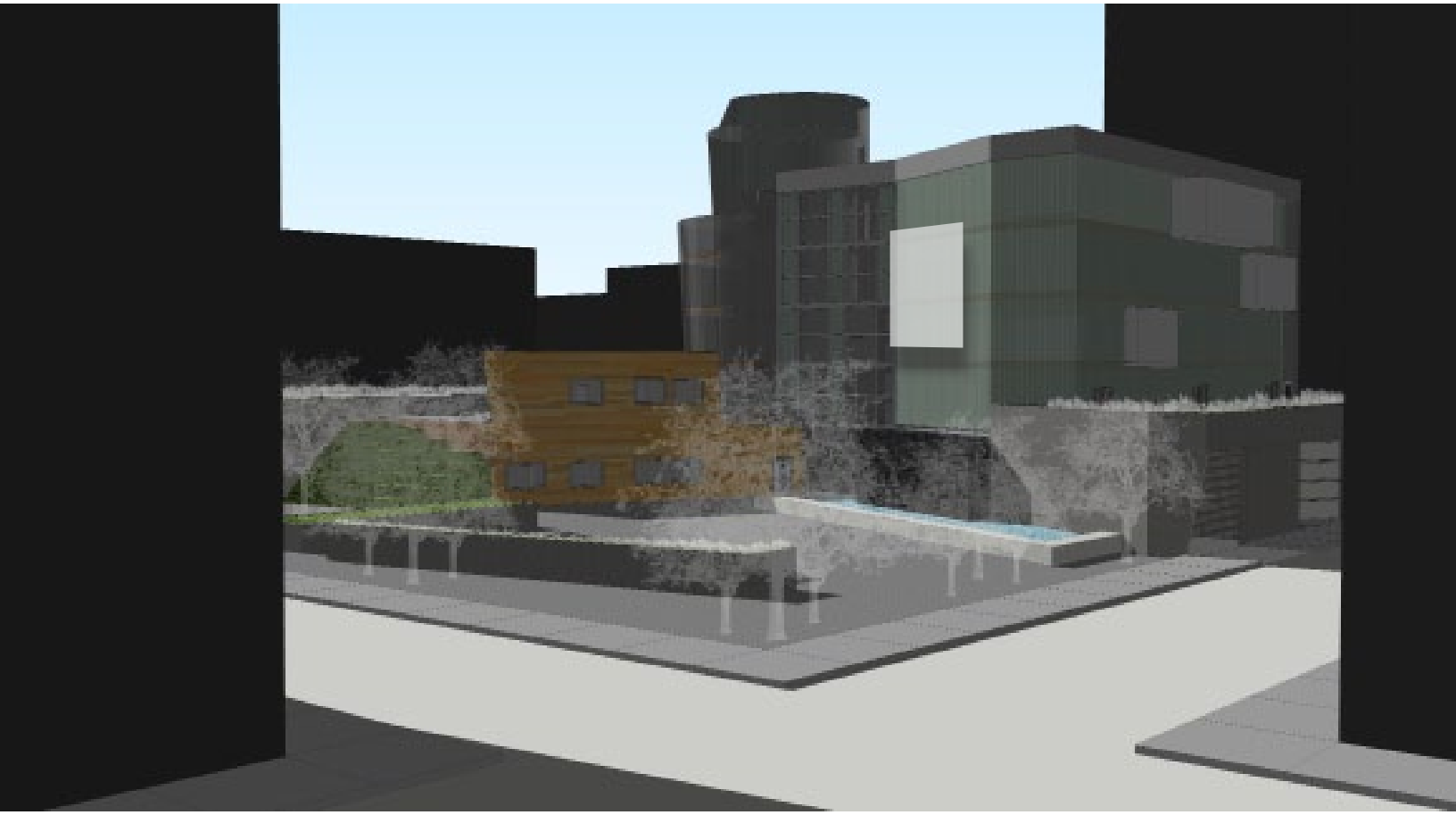
roof plan

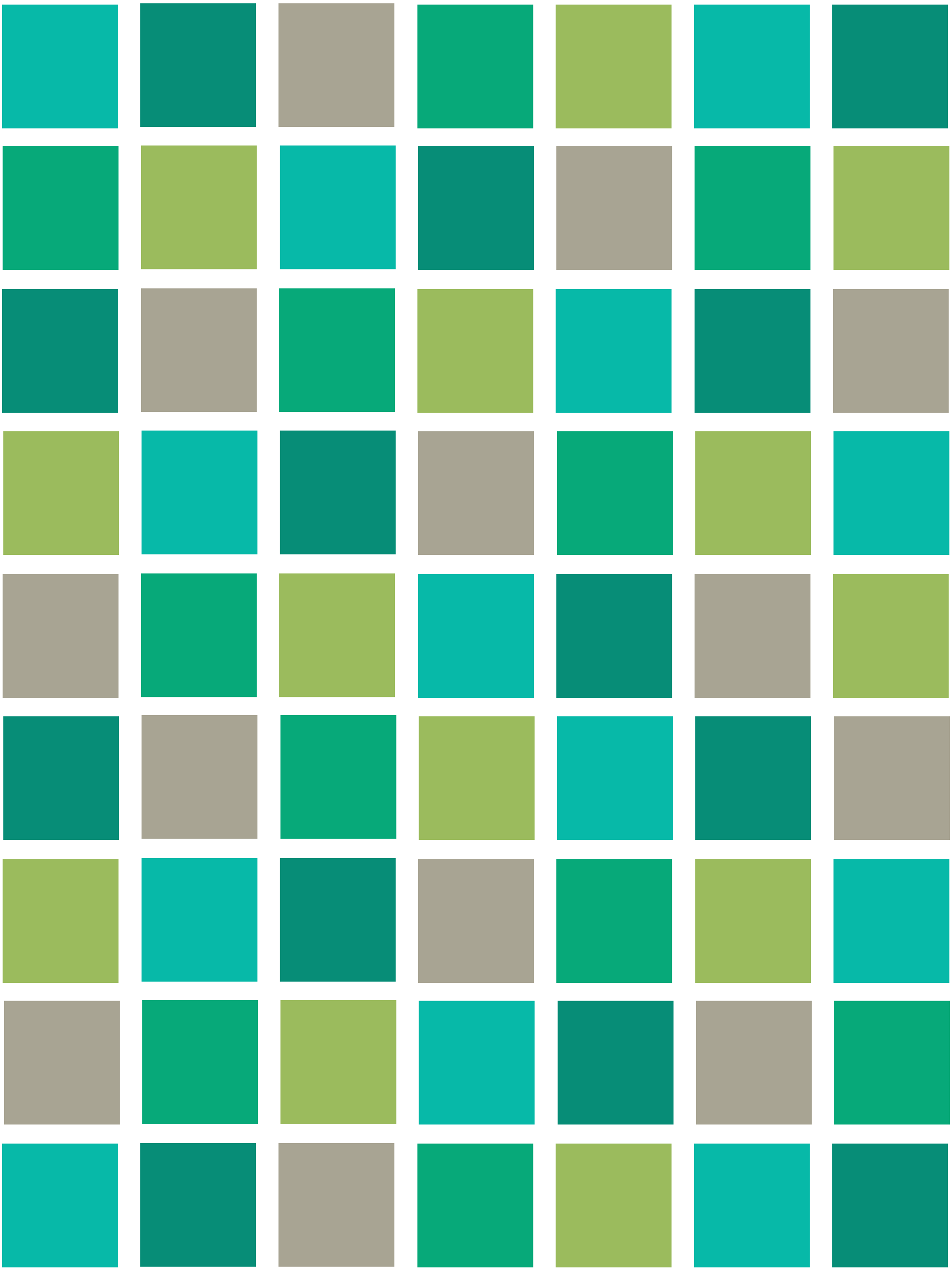
adaptability of spaces

Due to the complex nature of the coursework structure, an opportunity was presented for the building to adapt to its different uses. The floor consists of a modular structure, allowing for access to systems subsiding between floors (electrical, plumbing, ventilation, etc.). With this method, the students will be able to manipulate the building between semesters to create custom uses. The wall systems to be implemented would include non-loadbearing folding, sliding, modular or otherwise malleable walls on tracks. Also, the northern exterior wall would have the capabilities of expanding and contracting by the use of subset of electrical actuators, pushing out the facade and allowing for additional floor components to be put in place.



final design





references

Alter, L. “Nano Vent-Skin of Micro-Wind Turbines,” *Treehugger: A Discovery Company* (May 28, 2008), http://www.treehugger.com/files/2008/05/nano-vent-skin.php

Architecture Week. “Lecture Mario Cucinella: Sensibility, Creativity, Sustainability,” *Czech Architecture Week*, http://www.architectureweek.cz/en/lecture-mario-cucinella-sensibility-creativity-sustainability/

Architonic. “Product & Materials: Grune Wand Mobil, Art Aqua,” *Architonic* (2010), http://www.architonic.com/pmsht/green-wall-mobil-art-aqua/1101653

Bower, A. “Green Architecture at the California Academy of Science,” *Fast Company* (September 1, 2008), http://www.fastcompany.com/article/forces-nature

Braungart, M. & McDonough, W., ‘*Cradle to Cradle: Remaking the Way We Make Things*,’ [New York: North Point Press, 2002], 17-74.

California Academy of Sciences. “About the Building,” California Academy of Sciences: About the Building, http://www.calacademy.org/academy/building/

references

Chino, M. “Nano Vent-Skin: CO2 Filtering Solar Micro-turbines,” *inhabitat: Design Will Save the World* (June 04, 2008), http://inhabitat.com/agustin-otegui-nano-vent-skin/

Dezeen. “California Academy of Sciences by Renzo Piano Building Workshop,” *dezeen design magazine* (October 3, 2008) http://www.dezeen.com/2008/10/03/california-academy-of-sciences-by-renzo-piano/

Fritz, S. “Herbal Architecture,” *Architonic* (2010), http://www.architonic.com/ntsht/herbal-architecture/7000454

Fuad-Luke, A. ‘*ecoDesign: The Sourcebook*,’ [San Francisco: Chronicle Books LLC, 2008]

Gonchar, J. “California Academy of Sciences,” *GreenSource: The Magazine of Sustainable Design*, http://greensource.construction.com/projects/2009/03_California-Academy-of-Sciences.asp

Google Inc., “Portland, Oregon,” Google Earth (2011)

GorgeSearch. “Columbia River Gorge Geology,” e-Service (2008), http://www.gorgesearch.com/geology.htm

Guy, B. & Shell, S. “Design for Deconstruction & Materials Reuse,” Proceedings of the CIB Task Group 39 (2002), http://www.cce.ufl.edu/Design for Deconstruction and Materials Reuse.pdf

Guy, B. & Ciarimboli, N. “Design for Disassembly in the Built Environment: A Guide to Closed-loop Design and Building,” Pennsylvania State University (2008), http://www.lifecycle-building.org/files/DfDseattle.pdf

Hack, T. “Many U.S. Cities with Highest Literacy Rates Are Also Our Greenest,” *Big Think* (January 2010), http://bigthink.com/ideas/18401

Hattam, J. “Istanbul’s ‘Accidentally Ecofriendly’ Architects,” *Treehugger: A Discovery Company* (July 10, 2009), http://www.treehugger.com/files/2009/07/istanbul-accidentally-ecofriendly-architects.php

Hendry, E. R. “How Urban Sculpture Might Clean up the Air We Breathe,” Smithsonian.com (May 25, 2010), http://blogs.smithsonianmag.com/aroundthemall/2010/05/how-urban-sculpture-might-clean-up-the-air-we-breathe/

Institute for Sustainable Solutions. “Institute for Sustainable Solutions at Portland State University: PSU’s Hub for Cross-disciplinary Research, Teaching, and Partnerships in Sustainability,” Portland State University, http://www.pdx.edu/sustainability/iss

references

Institute for Sustainable Solutions. "ISS Name Change Announcement: PSU's New Sustainability Institute Takes "Solutions" Approach," Portland State University, http://www.pdx.edu/sustainability/iss-name-change-announcement

Institute for Sustainable Solutions. "Visiting Scholar Program," Portland State University, http://www.pdx.edu/sustainability/visiting-scholar-program

Local Climate Data from Portland Airport. "Portland (Airport and Downtown) Precipitation Data: Monthly/Annual Rainfall Totals (Downtown)," http://www.wrh.noaa.gov/pqr/pdxclimate/pg75.pdf

Local Climate Data from Portland Airport. "Portland (Airport and Downtown) Temperature Data: Monthly Normals," National Oceanic and Atmospheric Administration, http://www.wrh.noaa.gov/pqr/pdxclimate/pg6.pdf

Mario Cucinella Architects. "Centre for Sustainable Energy Technologies," *Mario Cucinella Architects*, http://www.mcarchitectsgate.it/index.php?id=19&projid=34

Moore, L. "21_rainforest_interior," image (October 2008), http://www.flickr.com/photos/30849383@N03/2911303267/

National Climatic Data Center. “Snowfall: Average Total in Inches,” *NOAA Satellite and Information Service*, http://lwf.ncdc.noaa.gov/oa/climate/online/ccd/snowfall.html

Oregon Travel Regions. “Columbia River Gorge,” *GoNorthwest: A Travel Guide*, http://www.gonorthwest.com/Oregon/columbia/Columbia_River.htm

PDXHistory.com. “Portland History,” PdxHistory.com (2010), http://pdxhistory.com/

Pearson, C. “California Academy of Sciences,” *Architectural Record* (January 2009), http://archrecord.construction.com/projects/portfolio/archives/0901academy-1.asp

Popular Science. “Best of What’s New 2008: Serious Materials EcoRock (2008),” *Popular Science Magazine*, http://www.popsci.com/bown/2008/product/serious-materials-ecorock

Portland Bureau of Environmental Services. “Portland Wastewater Treatment History,” City of Portland: Portland Bureau of Environmental Services (2010), http://www.portlandonline.com/bes/index.cfm?a=41962&c=31031

references

Quiroussoff, N. "A Building That Blooms and Grows, Balancing Nature and Civilization," *The New York Times* (September 23, 2008), http://www.nytimes.com/2008/09/24/arts/design/24acad.html?_r=1&adxnnl=1&adxnnlx=1292217312-dadhl7sBQz7oOuv6DGlrdA

Saieh, N. "California Academy of Sciences / Renzo Piano," *ArchDaily* (September 28, 2008), http://www.archdaily.com/6810/california-academy-of-sciences-renzo-piano/

Salmi, L. "Lantern-inspired Sustainable Research Building is China's first zero carbon university building," WorldArchitectureNews.com: The Global Resource for Architecture (October 10,2008), http://www.worldarchitecturenews.com/index.php?fuseaction=wanappln.projectview&upload_id=10474

Serious Materials. "EcoRock," *Serious Materials* (2010), http://www.seriousmaterials.com/html/ecorock.html

State & County QuickFacts. "Portland (city), Oregon," U.S. Census Bureau, http://quickfacts.census.gov/qfd/states/41/4159000.html

Top Box Design, “Research and Development Building in Istanbul, Turkey,” *Top Box Design: Architecture Design News & Pictures* (July 26, 2010), http://www.topboxdesign.com/research-and-development-building-in-istanbul-turkey/

TriMet. “Portland City Center and Free Rail Zone Map,” TriMet: Public Transportation for the Portland, Oregon, Metro Area, http://trimet.org/maps/citycenter.htm

U.S. Environmental Protection Agency. “Lifecycle Construction Resource Guide,” *U.S. Environmental Protection Agency*: Pollution Prevention Program Office (February 2008), http://www.lifecyclebuilding.org/files/Lifecycle%20Construction%20Resource%20Guide.pdf

U.S. Environmental Protection Agency. “Reducing C&D Materials,” *U.S. Environmental Protection Agency* (February 2, 2010), http://www.epa.gov/epawaste/conserve/rrr/imr/cdm/reducing.htm

U.S. Geological Survey. “The Geologic Histoy of the Columbia River Gorge,” U.S. Geological Survey (March 2001), http://vulcan.wr.usgs.gov/Volcanoes/Washington/ColumbiaRiver/geo_history_gorge.html

references

personal information

kathryn e. hughes
952.381.4118

13700 Parkwood Lane
Burnsville, MN 55337
k.hughesx@gmail.com