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Origami in Design : How can origami inform the design of the kinetic façade system?

Nicolas Ackerman

ORIGAMI IN DESIGN

HOW CAN ORIGAMI INFORM THE
DESIGN OF THE KINETIC FACADE SYSTEM?

Origami in Design
How can origami inform of the design of the kinetic facade system?

Approval of Thesis Research
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by

[Nicolas Michael Ackerman]

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Bachelor of Architecture

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Ch.1

Design Theory

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Research

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Precedents

Chapter 1
Design Theory

ORIGAMI IN DESIGN

HOW CAN ORIGAMI INFORM THE DESIGN OF THE KINETIC FACADE SYSTEM


ity Architecture Building

Thesis Statement

The present goal as a designer is to create a very thoughtful building that presents itself as a visual identity for our built environment. One of the intentions of the design is to not impact more into the co2 emissions. With 40 percent of the 75 percent annual global Greenhouse emissions coming from building operations,(Architecture 2030), we as designers must shift from a formal to a performance-based architecture. An architecture that instinctively addresses reduced energy consumption and therefore lower CO2 emissions through the integration of passive design strategies. In order to compete in a future with CO2 reduction, we must address building performance.

This thesis will examine origami's folding techniques and its kinetic potential within the integration of an architectural facade system. The goal is to create a climate responsive facade system that negates the use of energy while providing a better building performance. Some questions will arise such as can origami provide the necessary performance of architecture both visually and technically? Or can an origami inspired screening device be designed to kinetically shade a building and therefore decrease its energy consumption and inherently not affect CO2 emissions?

My thesis will examine the multiple typologies and uses of origami with a degree of complexity. Initial experiments will address solar gain and daylighting, other experiments will address issues such as human comfort and visual appearance. These performances will then help guide us to innovative architectural solutions that question the typical design process. The result of the thesis will be a scaled origami system that will then be employed in a design project and ultimately be applied to real world applications.

Keywords : Kinetic architecture, Origami, activated spaces, sustainability, interactive, responsive

Poster by Author - Showcasing the use of origami as a facade system for our design and buildings. The use of the folds as a shading device

Abstract

The priority of this paper is to provide an understanding and knowledge of kinetics in architecture through producing data on origami-inspired solar screening devices. The world is constantly changing, and becoming more negatively affected by our built environment. As mentioned, the annual global greenhouse emissions is at 75 percent, and approximately 40 percent being the sole operation for the building to succeed in its environment(Architecture 2030), the ideology of making our buildings more responsive is in question. With this thesis, there will be the exploring of two responsive methods, the kinetic facade system and the adaptability of origami styles. The overall goal and objective of this thesis is to examine the folding motion of origami and apply it to kinetic facade systems.

The experiment will go to a degree of complexity by first showing the flat sheet, then to a pattern, then to the origami, and finally to kinetics, all while showing the performance of each sequence. The question that the thesis will ask is can origami make architecture more adaptable and sustainable? The research methods will be based on the modeling of origami structures while examining different typologies of origami and the study of kinetic facade precedents. This evaluation of kinetic potential of origami will help in the elaboration of the built product. The built product being a scaled origami system that will then be deployed in design applications.

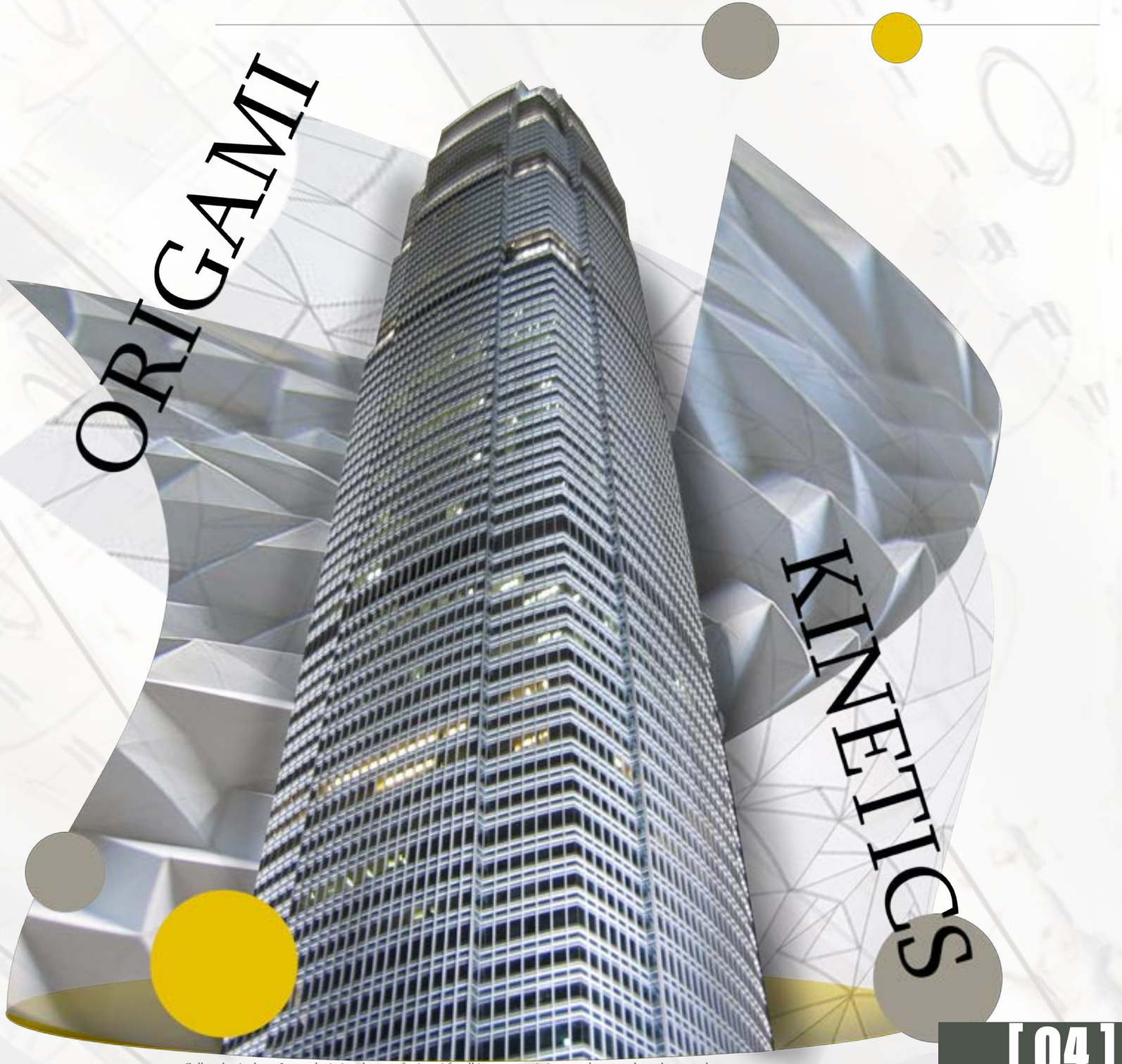
Collage by Author - Image depicting the use of origami on building faces.

Introduction

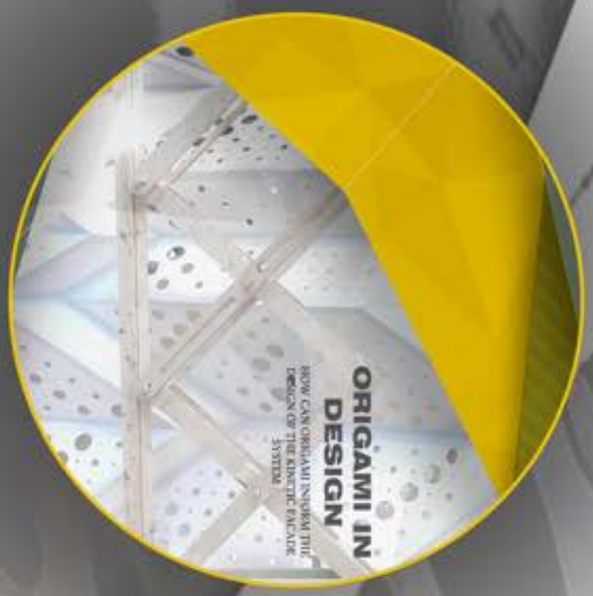
Our built environment, especially the built operations, has negatively affected our environment. The way our buildings maintain and operate to sustain our human comfort has gone too far into the increasing mass of co2 emissions. Architects must have the ability to understand the built environment and the changes that come along with it. This is why some of the major design issues architects face are related to the opportunity of adjustments. Issues such as the shift to sustainability to protect the environment, or the needed use of natural light rather than artificial light, or the transition of architecture to be more artistic and interactive. Some major design thinking comes to acknowledge that the weather, climate and future will change. It is for that reason that design methods and architecture should adapt to these changes.

The stance of this thesis looks at implying the use of kinetics facade systems with the collaboration of origami folding adaptability. The research will show that not only will the origami facade systems lower energy costs, but also the positive effects towards building performance with human comfort and visual identity of the structure. This thesis will focus on the main elements of adaptability towards heat gain/heat loss, the human comfort of the users, daylighting, and design appearance with the suggestions of origami implied facade systems.

The main objective is to provide data that the integration of origami and passive design systems should reduce energy consumption and therefore reduce CO2 emissions. How will this be done? By displaying the technicality of the sheet and its sequence into becoming origami, and eventually into a kinetic facade system. The kinetics of this project will be to look at actuators and the best way to embed them into the origami. Looking at the best typology of origami, the most effective type of kinetics, and the least energy use of actuators.



Collage by Author - Image depicting the use of origami for all instances-existing,new, long envelope,short envelope,etc.



Chapter 2
Research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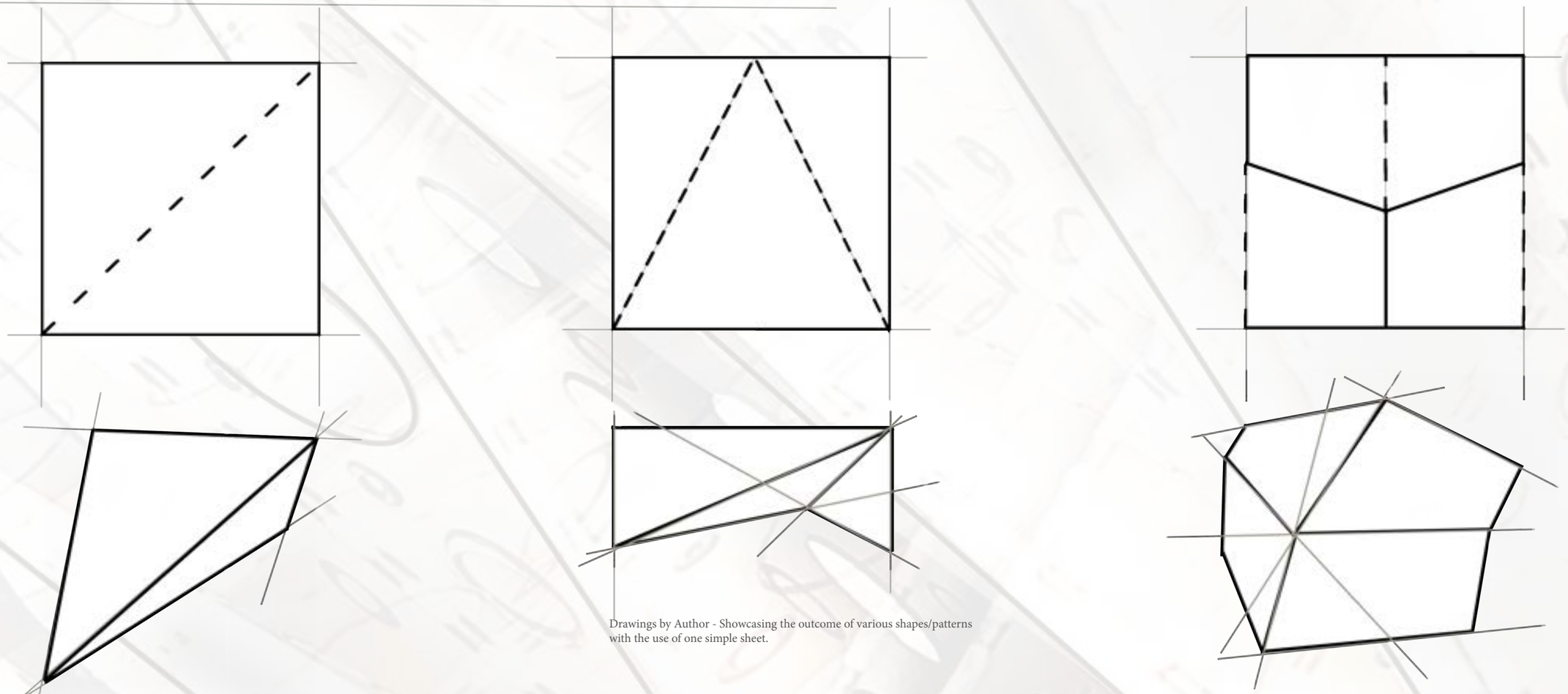
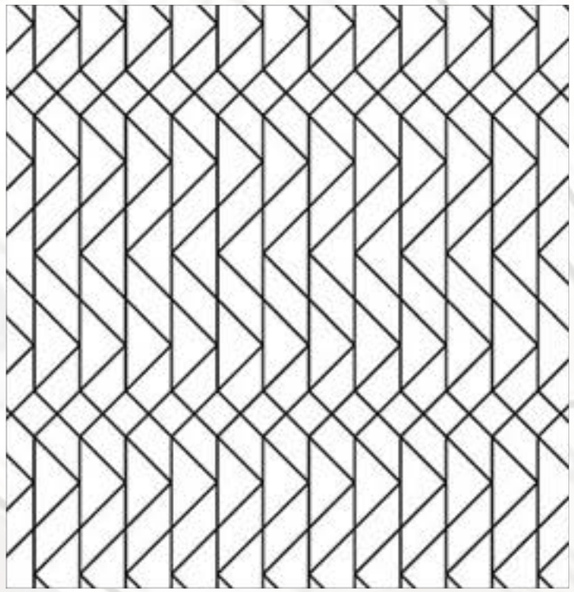


Drawings by Author - Showcasing the outcome of various shapes/patterns with the use of one simple sheet.

To first get into a system of origami, we must first understand the meaning and origin of the word. The word origami comes from Japanese pronunciation where "Ori" means folding, and "Kami" means paper (Nick Robinson, 2023). So in its origin it means the art of folding paper. But looking at origami without cultural origin can mean the technique of folding.

The goal of this art is to transform a flat sheet into a three dimensional form using the creasing and folding techniques. What is unique about origami is that it can have many different variations from just one material. This is because of the geometry, shapes, and folding patterns that can come from that one material.

The basics of origami is to have it all interconnect and vary from the patterns that have been created. Origami started off as just a square that would then be transformed, but quickly changed to different shaped paper and different outcomes. Now the origin of paper folding is hard to track, but its influence on culture can be determined. From Japan, to China, and soon the Europeans, the art of folding has changed and greatly improved in design. The paper material has been made stronger and the shapes have become more sophisticated, from square to hexagons and octagons.



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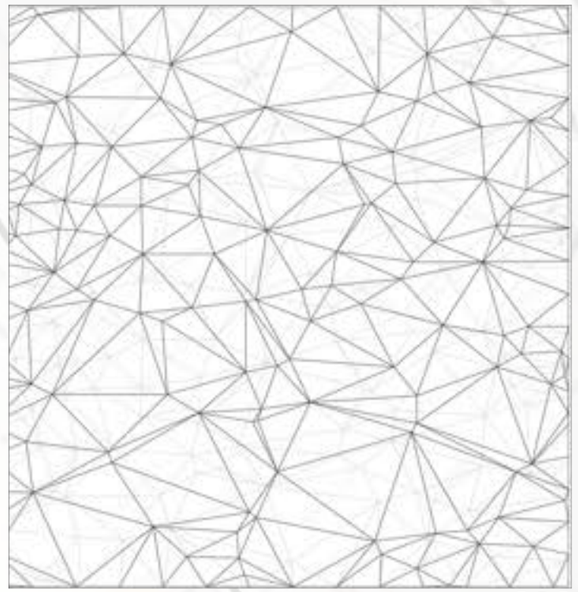

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Now what greatly impacts origami is the obvious connection between the geometry and origami. Folders of Japan have used geometric patterns to recreate regular anomalies and in today's world of technology, we use computers to fold more origami designs, (https://www.ics.uci.edu/~eppstein/junkyard/origami.html).

This change in your desire media has impacted what it would create. Where old methods of origami was to create figurines, new methods help to create spaces and facades. Even though there are different methods, there is always a connection back to the geometry drawn on your paper. Geometry is just as important as where you start on your piece of paper, just like any design, what you choose in configure will greatly impact the final product. The pattern displayed on a piece of paper will affect the folding capabilities of the material and in fact change the geometrical volume.

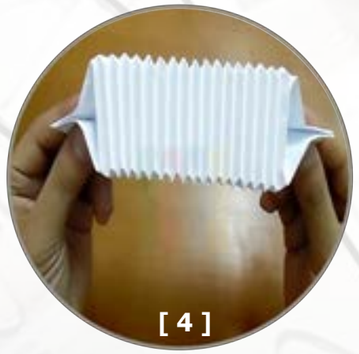
Now with origami, the geometry affects the typology of the origami and the use of its form for a certain project. Which is why origami is so great because there are multiple variants that produce the necessary outcome for a situation. Because origami can be decorative and functional all at once. Where the initial geometry seems to be picked due to structural reasonings, it could also help with foreground where the geometry begins to make a pattern for a person to view. Or in this thesis, the reasoning for the chosen geometrical pattern was to use the form to provide overhead shading and to bring a new visual identity to a building.

Types of Origami Styles

There are many different styles of origami, in fact over 80 different styles just in the art of folding. However most are involved with the Japanese tradition of animal making origami. Nevertheless there are still some styles that inherit form, space and volume of architecture. They are action origami styles, modular origami styles, and pure-land origami styles. All of which are unique in cease pattern, geometry and attributes. **The action origami style** is an addition to standard still origami, where the element of movement is applied to the origami. This style uses the kinetic energy of the user's hand to apply motion into the form. A great example would be the accordion style origami.

The accordion style origami refers to the folding technique of alternating folds to create a pushing and pulling motion. It is composed of linear divisions with same size shaped divisions all to collapse on itself. Its function is to extend and collapse through a plane or volume. Another great example of action origami is the rolling style origami. This one is pretty self explanatory, the rolling style origami has the motion of rolling upon itself. It is similar to the accordion style origami in which it expands and contracts making it bigger or smaller in nature. The geometry that takes place in this form relies on the ability to roll over such as a circle being cut into same sized shapes throughout the diameter of the circle.

Now this style of origami sets as the foundation for other styles. Meaning that the action of expanding and collapsing can be seen in other methods of origami. This is vital for this thesis because it involves an action of movement, where it can adapt to different movements of the sun.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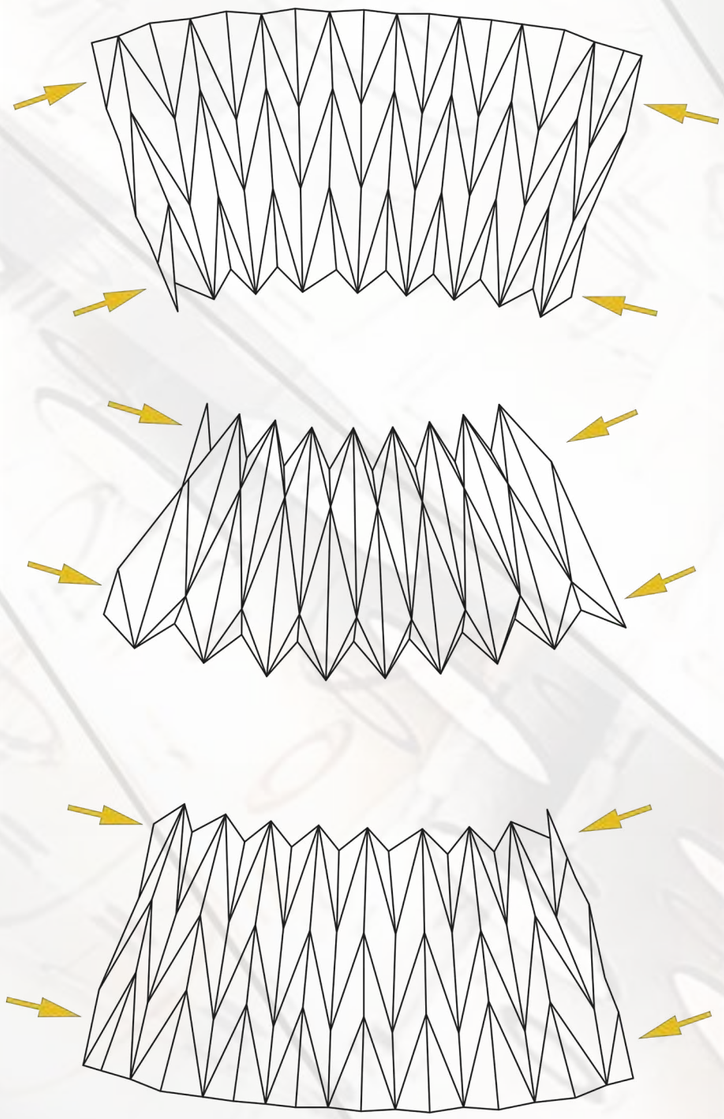

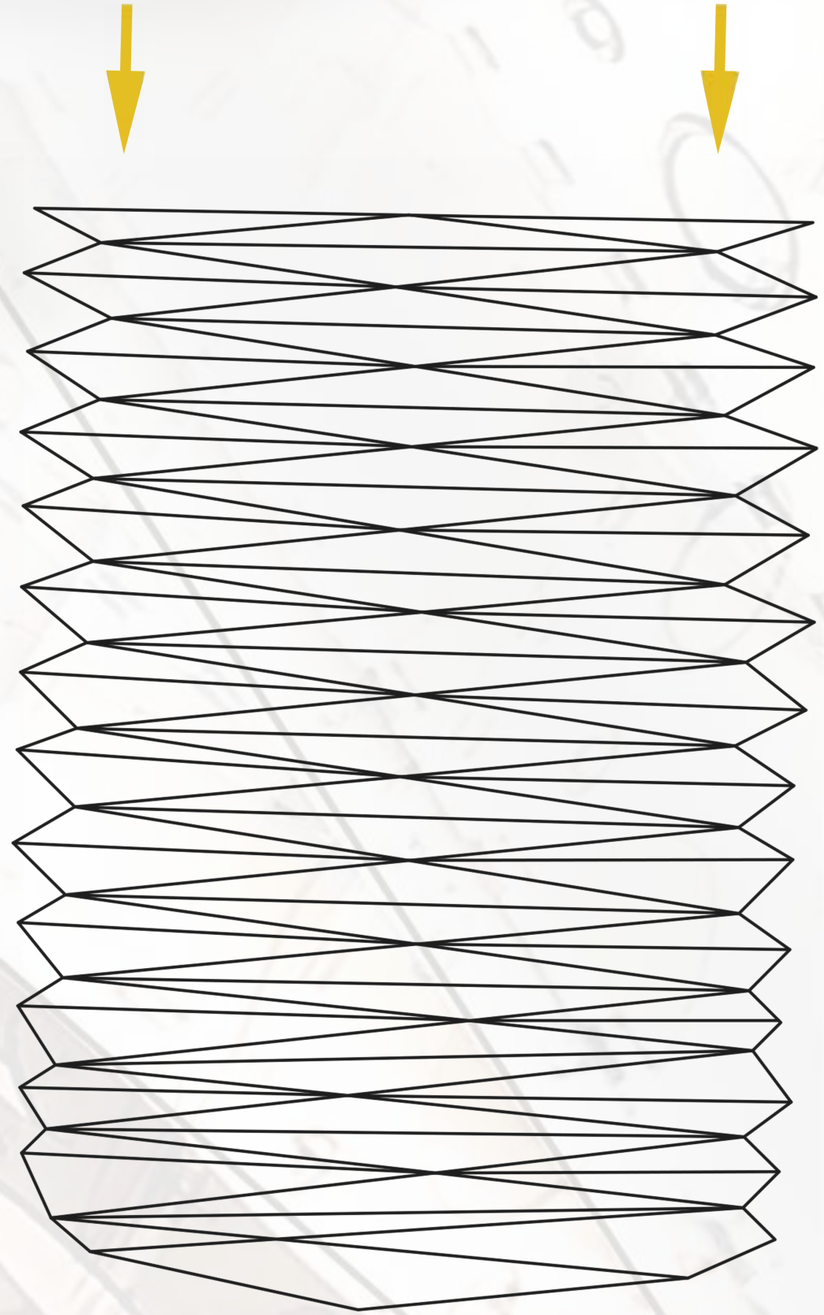

Image from Author illustrating the origami style Action Origami

Types of Origami Styles

The Modular origami style is where the style uses similar modular pieces to make a larger complete model. The modular pieces themselves are pretty simple and result in a more difficult assembly. Some examples of this modular origami style would be the Lattice work and the flower module style. The lattice work or Mashrabiya style origami takes place of Islamic culture. The design is composed of lines forming the function of the Islamic window where it becomes an architectural element in design. This style uses the motion of opening and closing, such as a window, and becomes a nice architectural art. The main geometry of this pattern is modular triangular pieces in which it can be configured into a circle which makes it easy to open and close. The fold-finding or flower module style origami hints in its name that it is taken inspiration from a flower. The modular geometry of the flower comes together to make sculptural art. Where the pedals lead away from the center of the flower. This method is also taken into account in origami. This technique allows for a stable plane of geometry with the structure being held in the center, such as a flower. And lastly the pure-land origami style.

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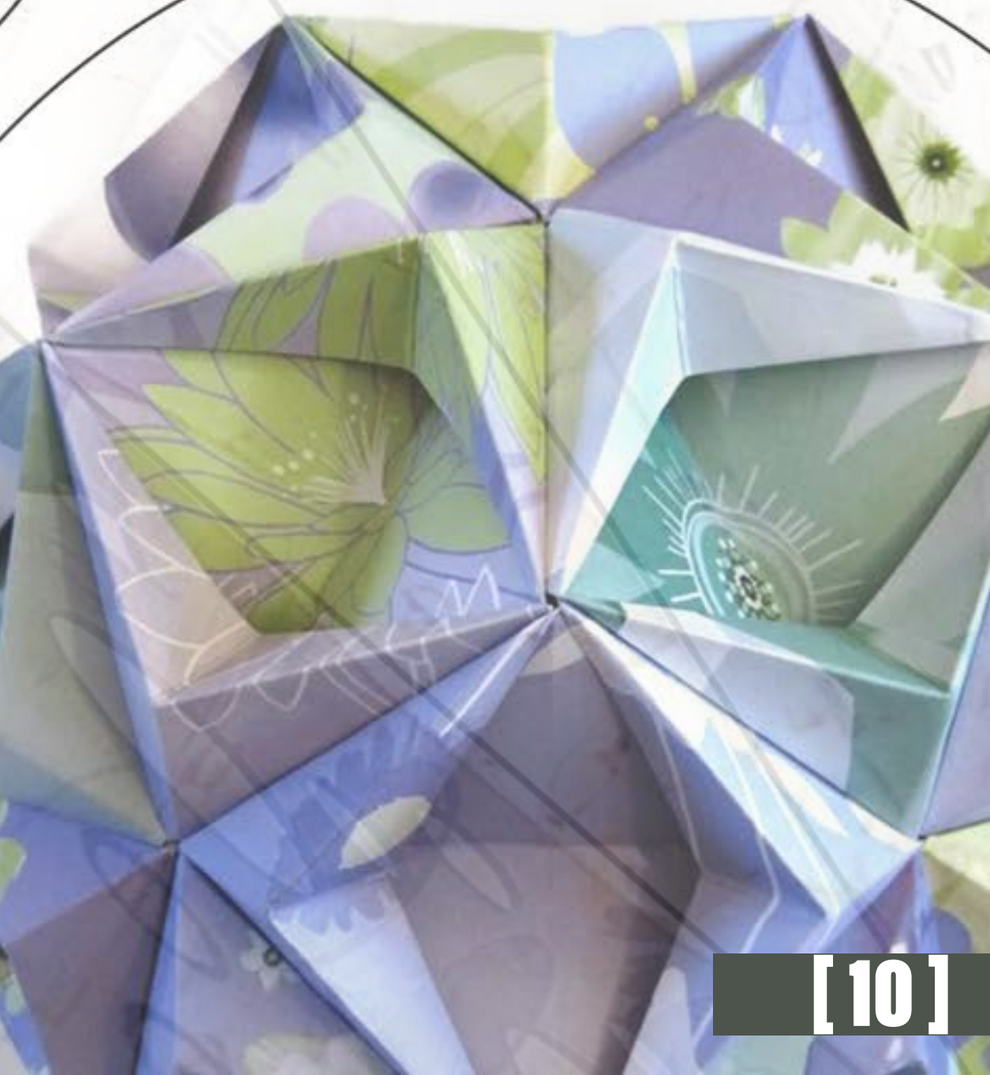
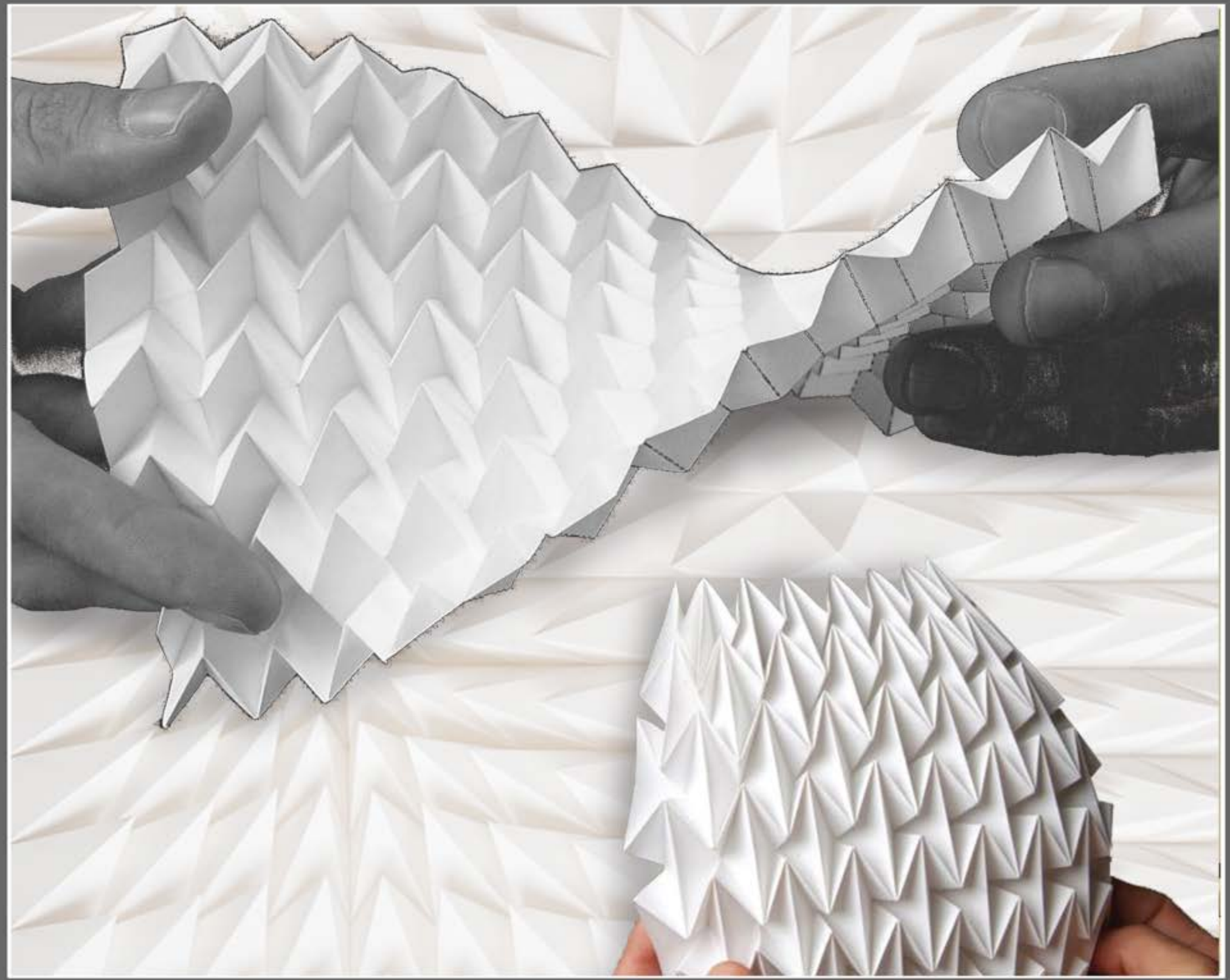
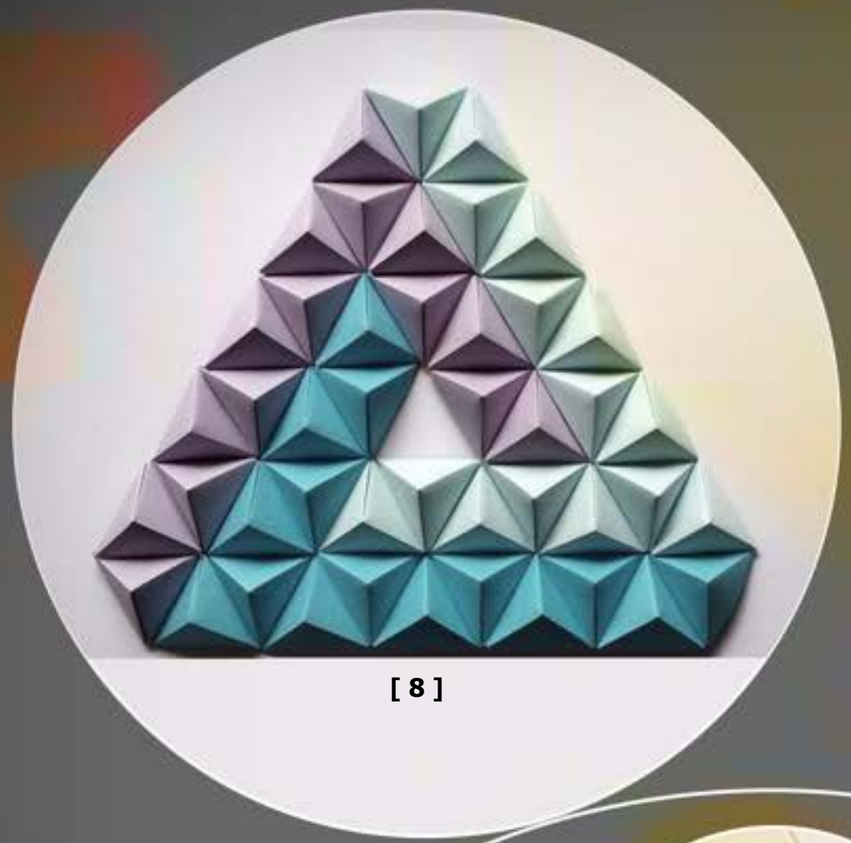


Types of Origami Styles

The pure-land origami style restricts itself to only using mountains and valleys to construct its form. An example of this style would be the Miura pattern style. The Miura pattern style origami is unique in its characteristics. This form of art folding is made in the form of "mountains" or "Valleys" in which the mountains or valleys alternate from another in a zig-zag pattern. It is unique because the alternating weight of each layer balances within the origami. So the guide throughout the pattern is self supporting and due to the relying pattern, it can flex and have the ability to be configured into any shape.

For this experiment, we are going to be looking at the miura ori pattern because of multitude of reasons. For one, it has similar abilities of the action origami style in which it can collapse and expand when need be. Another reason is simple fabrication. When this facade is meant to be build we want to create a simple process of construction. And finally the key reason for choosing the miura ori fold is because the folds and valleys of the geometry. This origami can shade itself with the mountains and valleys that it creates in its design.





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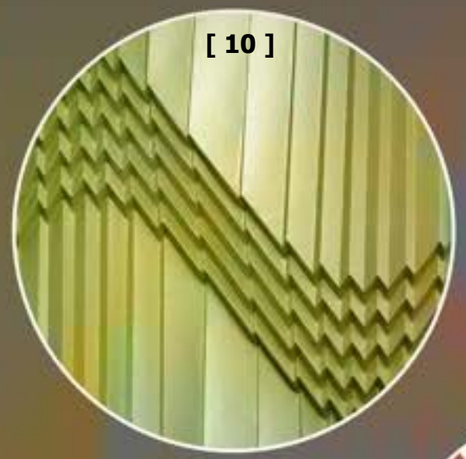

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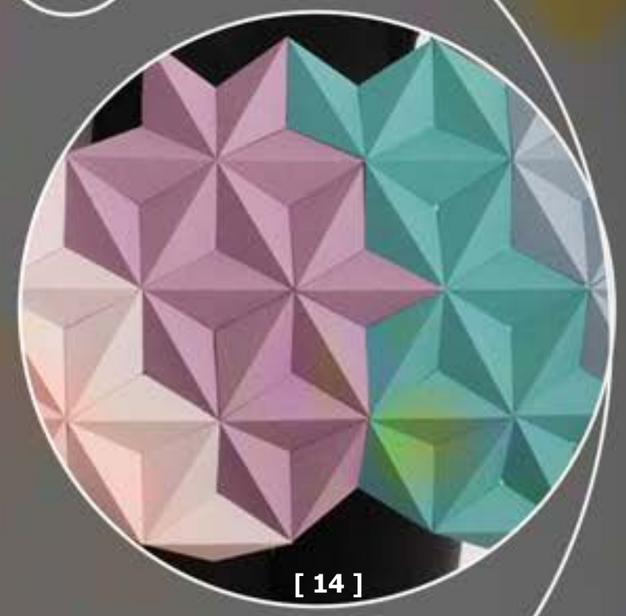

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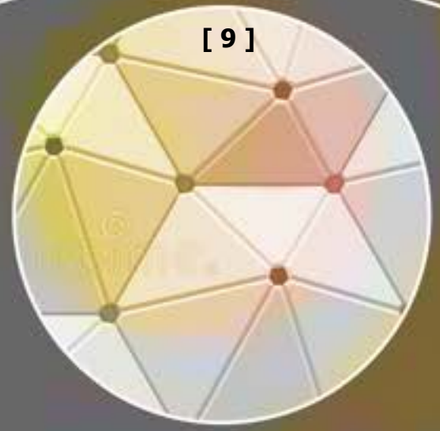

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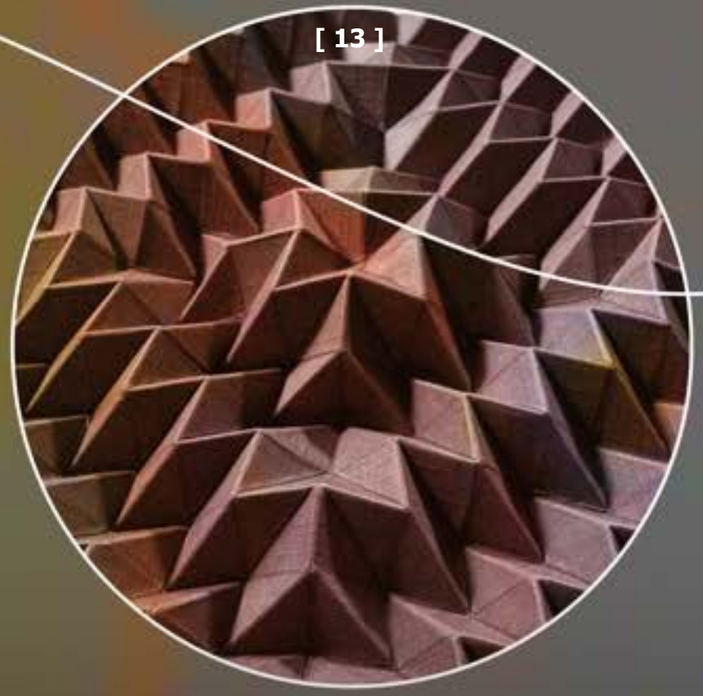

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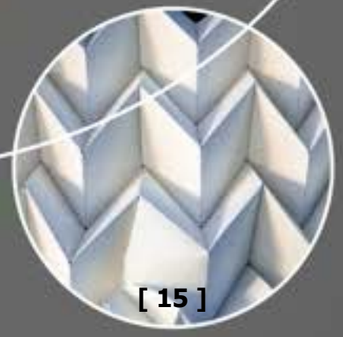

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When using origami into architectural designs, there comes this outcome of great strengths, whether it be performance or aesthetics. For origami there are many benefits listed such as structural integrity, the simple materiality of one sheet, adaptability, interior and exterior visual identity, and easy control of the system. These benefits listed are why I chose origami to be used as a shading device.

Starting with **structural integrity**, the origami has the ability to become structurally sound with the geometrical pattern it has displayed. Carrying its own weight and load without the use of exterior references. "Since the paper folding technique is sturdy and self-supported by itself, the structure does not need complex structural designs". Also that "As forms are constructed out of folded paper, the form's structural stability as well as its practicality is understood"(WTN, 2023).

Speaking of one sheet, we will look at the strength of origami with **materiality and controlling of the system.** As mentioned before, origami is the folding of one sheet, which becomes the affordable and compromising ability to control the system with one motor. Also to enlist one material as the backbone of the architectural design makes the fabrication and expenses process much quicker and easier.

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On our third list is **visual identity**, we looked at performance base attributes, now it's time to bring out the art of architecture and talk about the benefits of using origami for exterior and interior aesthetics. Because of the unique and symmetrical pattern of origami, it makes a building face "pop out" when applied as a facade system. Also with the perforation, the ability to visually see into and out of a building. For the interior, the origami sheet allows for two faces. For the face showcasing into the glazing window, A design can be implicated to the owner's liking, while the exterior face can be something completely different.

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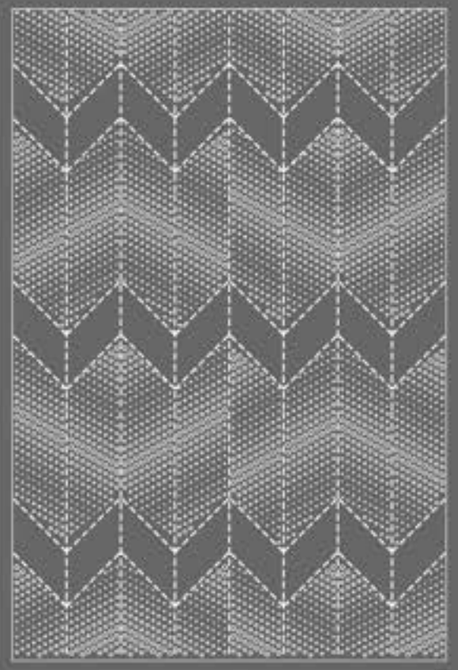
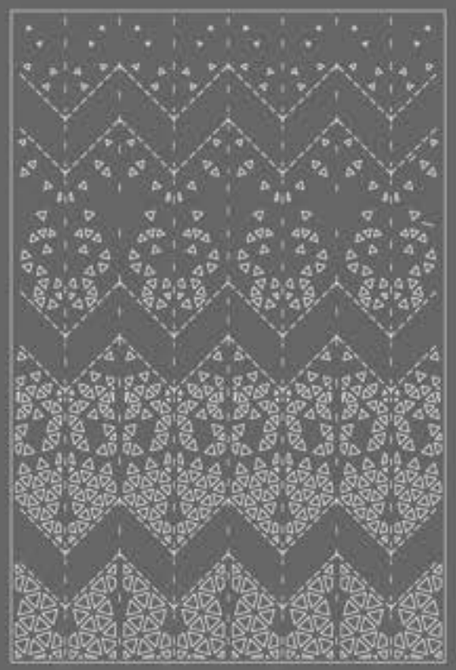
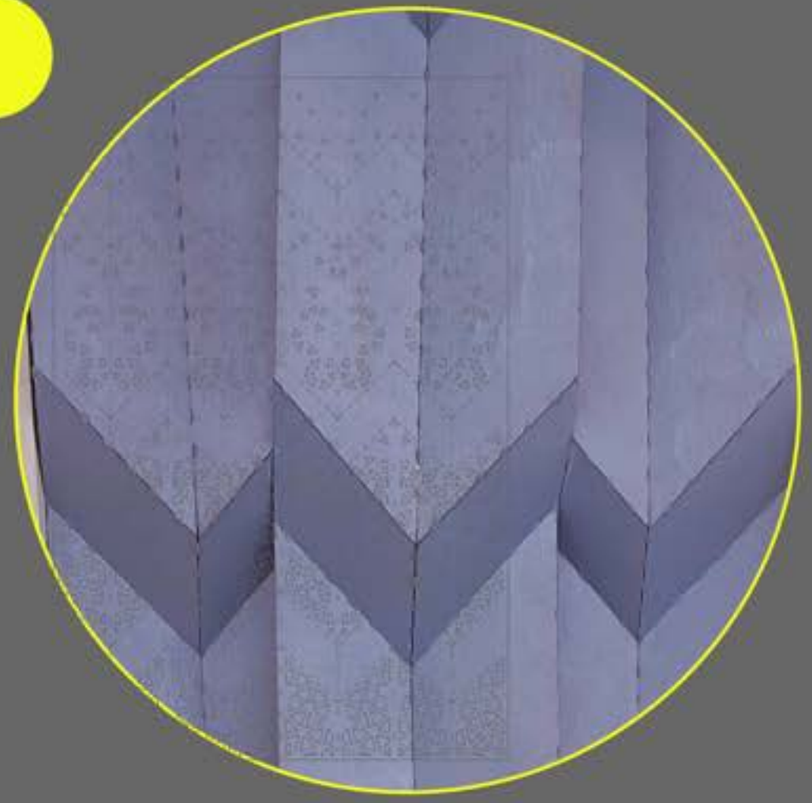
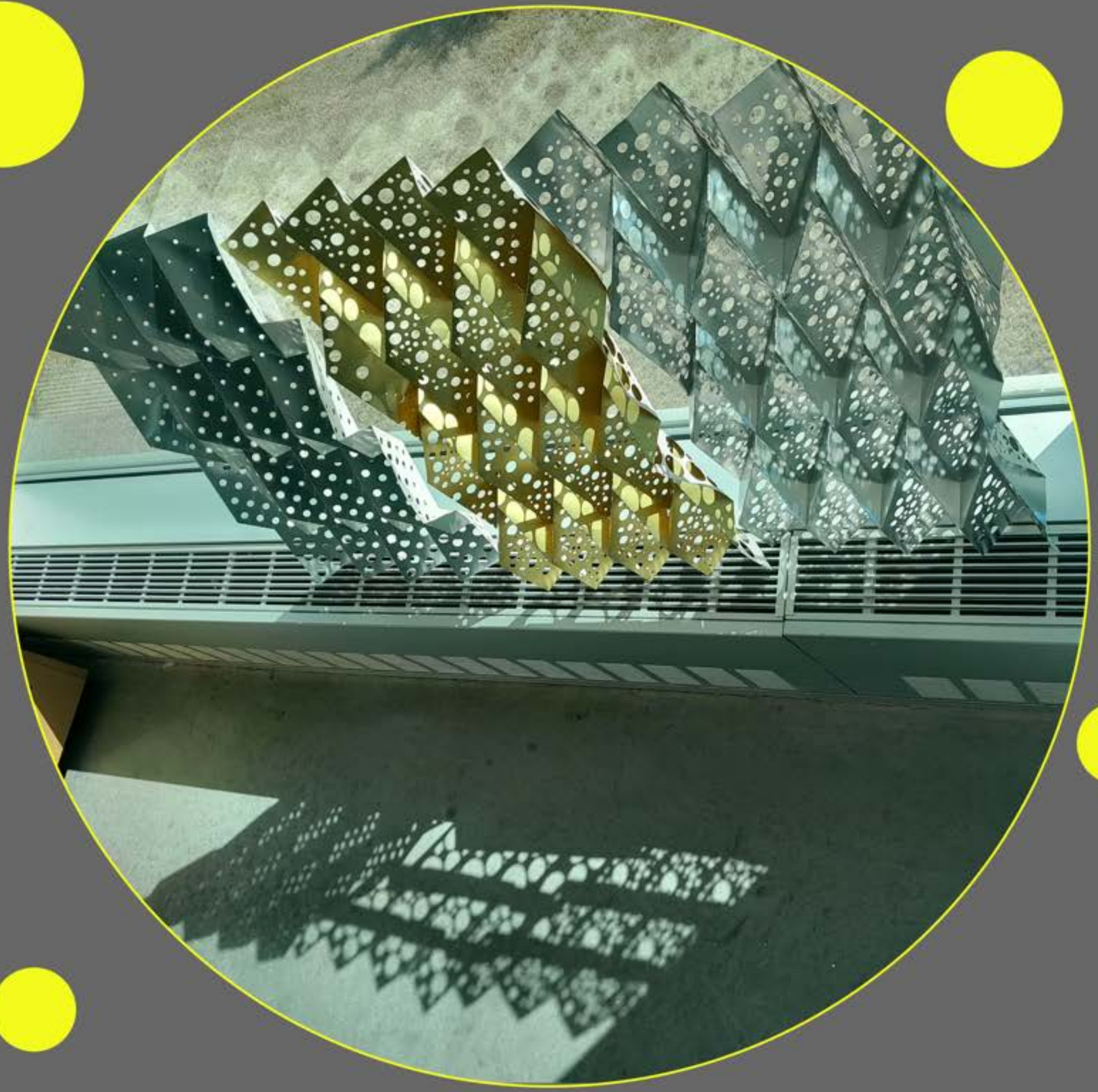
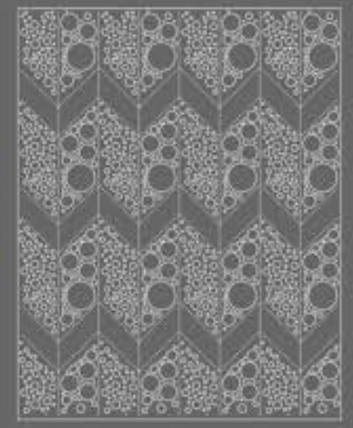
And lastly the most important benefit of origami is the **adaptability** of the system if applied to kinetics. This ability is most important for this thesis research because it needs to adapt to the sun's complications. Making the new facade system into a responsive shading screen

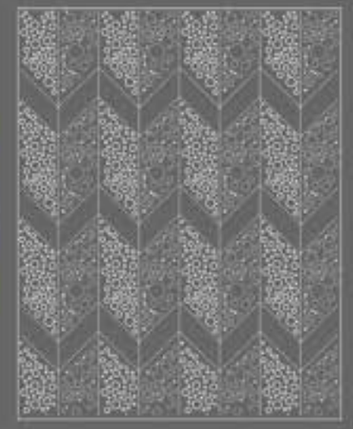


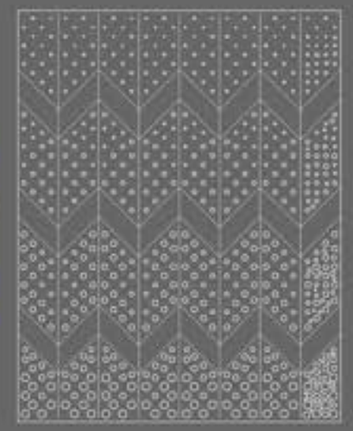










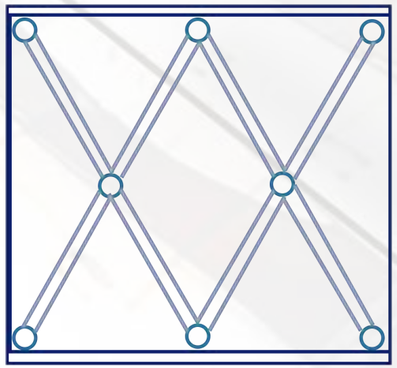


What are Kinetic systems

To look at kinetic systems we have to look at the definition in part to describe it. The word kinetics in the dictionary is relating to or resulting from motion. The word systems relate to a set of things working together in an interlocking connection. So a kinetic system is the movable design of multiple parts in an assembly. And these types of systems have been part of architectural design for many and many methods. Architecture has been involved with kinetics for a long time. It made its appearance with the doors and windows first. Where these doors and windows would move and provide necessary ventilation to a structure to further cool the building. Then these systems started to play a larger role in energy efficiency and swiftly started to become facade systems and roof assemblies which help with adapting the building to the time of year.

However kinetic systems are not always enough in helping the building operate, despite their importance in utilization. Some become over complicated, require too many movable parts, or use more energy to operate than the intentional amount to save. Which is why the mechanism of the kinetic system plays its part as well. When picking a mechanism, you need to look for the length the kinetic facade will move,rotate,position,etc. Also the load capacity of the kinetic facade. The mechanism which correlates with the kinetics needs to be able to hold and provide motion to itself. These things are what we need to motivate a working and successful facade. Nevertheless they do adapt to change and are an additional method in architectural design decisions for design issues. With that in mind, we must look at the types of kinetic systems that are used in design making decisions. Referencing from Fox and Yeh, there are three types of classifying kinetic systems. The three are Embedded, Dynamic, and Deployable.

Embedded kinetics are kinetic systems that are fixed and integrated into the architecture as a whole. The purpose of the embedded kinetics is to respond and change the large scale architecture into the necessary output of environmental and human factors. Some of the mechanical methods that employ this system are axial, rotational, linear, etc. Dynamic kinetics are systems in which they are an independent component of the whole architecture. They serve a purpose in a partial piece of the assembly. " Examples of these include louvers, doors, partitions, ceilings, walls, and various modular elements' '(Michael Fox). Its function serves the same but at more various parts. Lastly, deployable kinetics are systems in which they exist temporarily and easily transported to be deployed. These systems are great for easy construction and timely changing attributes. With all three in mind, we have an understanding of the adapting abilities of these systems in which they can be integrated and help with changes needed for the building.



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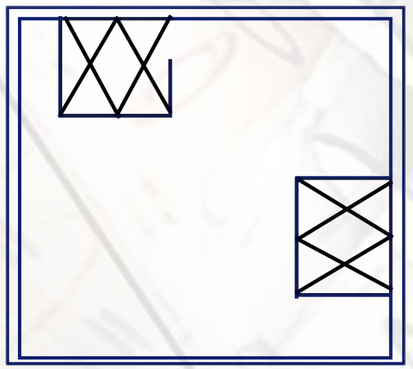

Dynamic

Deployable

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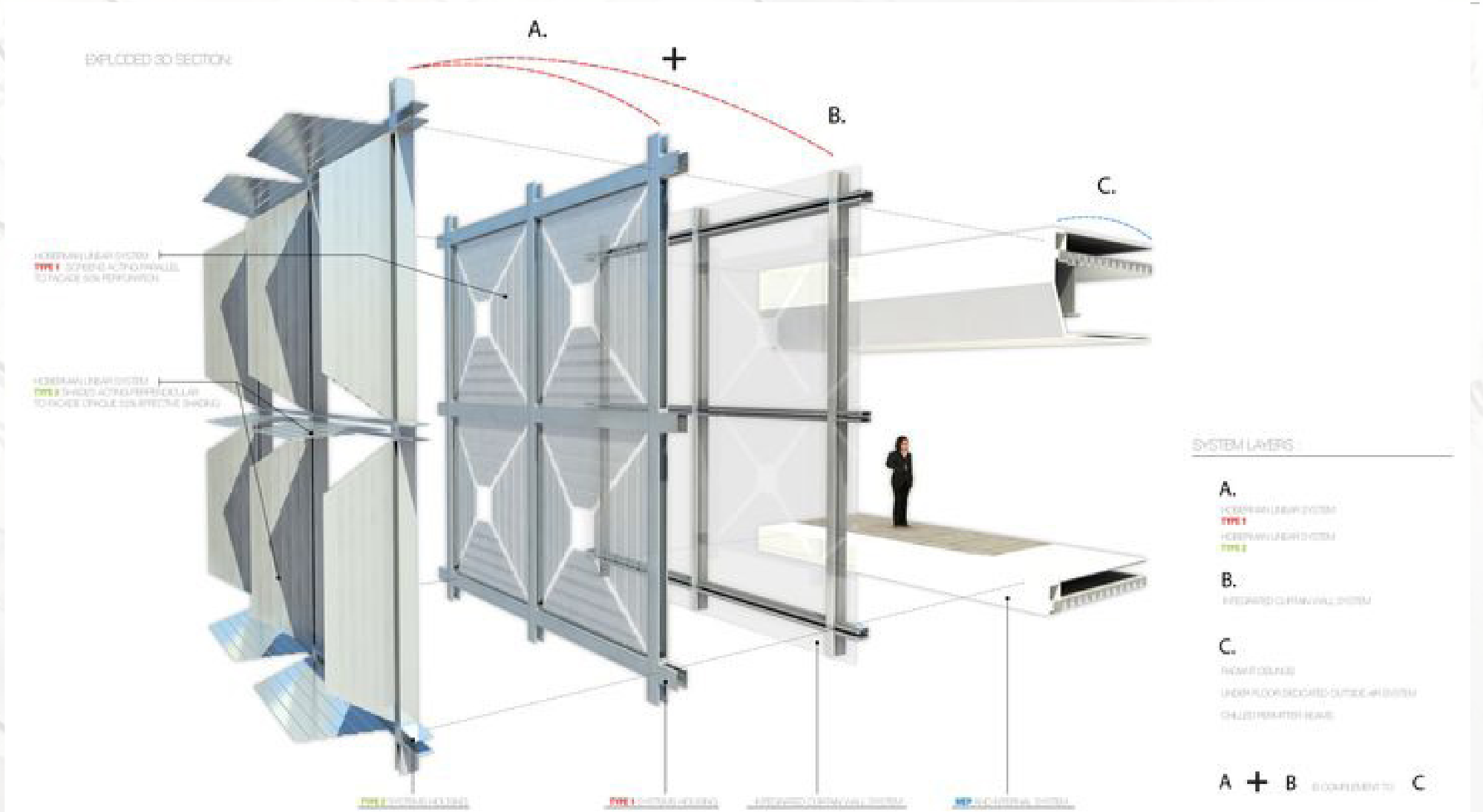
Facade Systems

The facade system is a form of construction that provides an additional element to a design. When first thinking of facade systems, we think of a component that is part of the building envelope. A system that "compromises the structural elements that provide lateral and vertical resistance to wind and other actions" (steelconstruction.info). But as the designs got more complicated, these systems started to provide more. They start to become an artistic appreciation of the building, or the protection of external forces such as the sun. Now, facade systems start to take shape in a movable facade system, known as kinetic facade systems. These systems help greatly with adapting to conditions of the environment and help to sustain the building life. Lilly Cao from Archdaily states that Kinetic facades can and have taken a multitude of forms throughout the years, and that they often mediate between aesthetics and utility, (Lilly Cao, Archdaily). Kinetic facade systems have been fighting to provide better building performance to the built environment, which is why the facade system would be great to further work the function and artistic value by compromising it into origami strategies.



Actuators

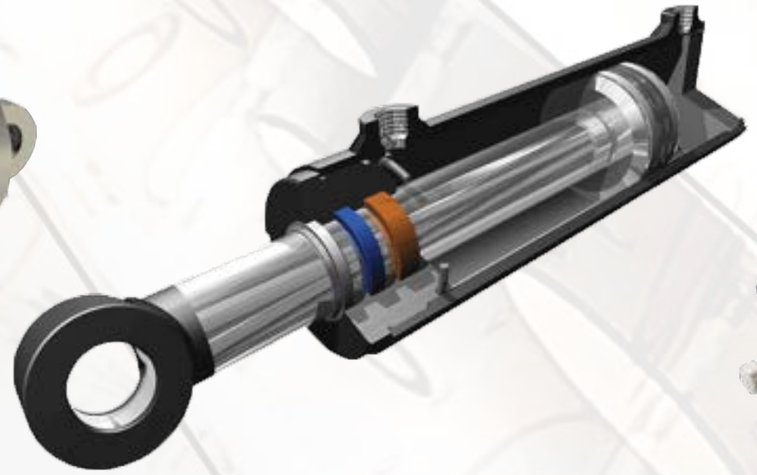
Now we talk about this origami structure being embedded into a kinetic system, but exactly how will it be deployed? Well for this we will be looking at a device that is most commonly used in facade systems, which are actuators. Actuators are a device/mechanism that cause a machine to operate, or in our case, for our facade to operate.

Just like the types of origami ad types of kinetics, there are different types of actuators. These range from the motion they provide. There are linear, rotary, pneumatic, and hydraulic types. The linear and rotary are ones that provide motion into the linear axis or in a 360 degree motion. These become very useful into situations of great movement with little resistance. One of the issues with these devices though are the input to work which is battery/energy driven. But just like any device, they require little input for great output. The next device is the pneumatic which is air pressured instead of electric. And similar to this device is the hydraulic which is water pressured. Both the pneumatic and hydraulic can be used for linear and rotary motions. The device such as the actuator would be greatly ideal for the use of this thesis in providing the necessary kinetics to our origami.

linear/stepper motor based

rotary motor based

hybrid motor based

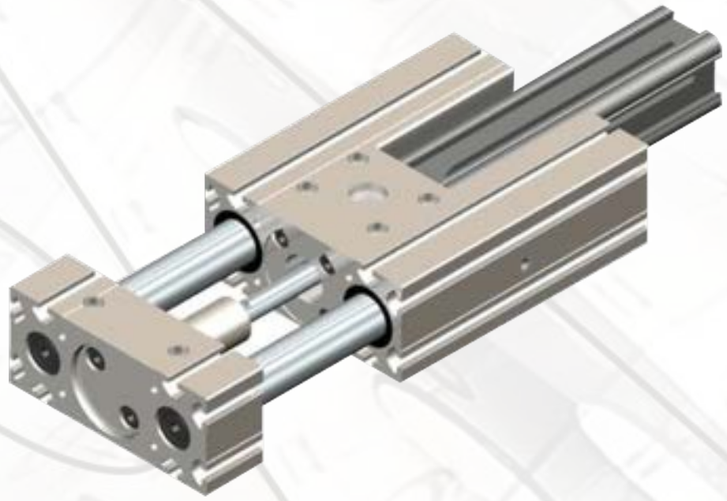


All images from Homedepot.com , theHopeGroup.com, and Nanotec.com - These images illustrate the different kinds of linear actuators/cylinders vs hydraulic systems.

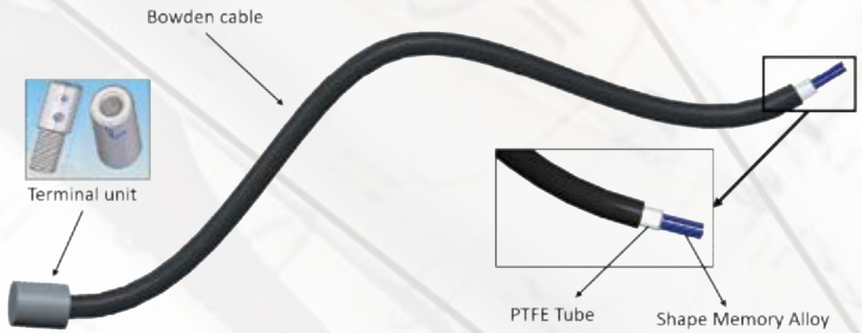
Actuators

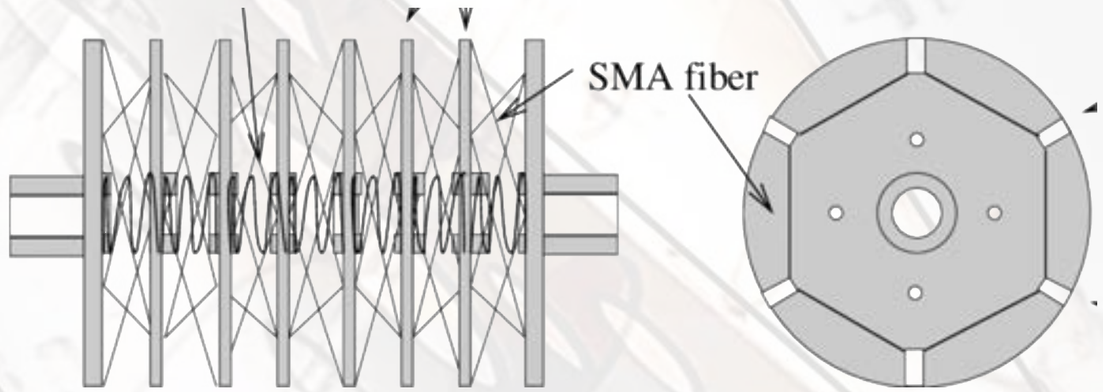
The motor based actuator is a device that uses electricity to create motion to a mechanism. The motor based can be linear, rotary, or a hybrid of the two. This technology takes direct current and applies torque. Depending on the type of motor base device is used, you will have the electricity applied to an objects movement in that axis. The motor based actuator is a device that uses electricity to create motion to a mechanism. The motor based can be linear, rotary, or a hybrid of the two. This technology takes direct current and applies torque. Depending on the type of motor base device is used, you will have the electricity applied to an objects movement in that axis.

With an understanding of helpful origami types, which could help with factors of design decisions, and the information of kinetic systems with their adaptive abilities, this research can now look at mechanisms of applying both categories into a single system. This would be the creation of origami kinetic facade systems. Overall we want to look and see if origami kinetic facade systems can provide better adaptation and better building performance. This research will look at sets of case studies that use this mechanism of origami kinetics and provide data in which they help with design factors. The case studies will be arranged by looking at the three types of origami - action, modular, pure-land, and the three types of kinetics - embedded, dynamic, deployable. The specific site of this research will rely on the context of building needing to be adaptive.



All images from Homedepot.com , theHopeGroup.com, and Nanotec.com - These images illustrate the different kinds of linear actuators/cylinders vs hydraulic systems.



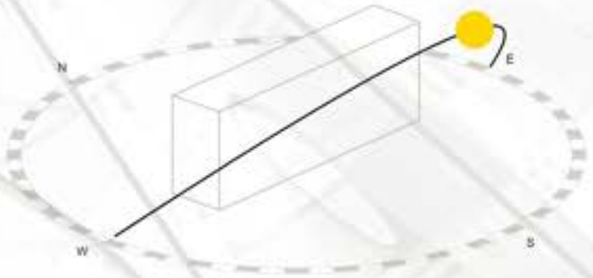


Research of Sun and Shading

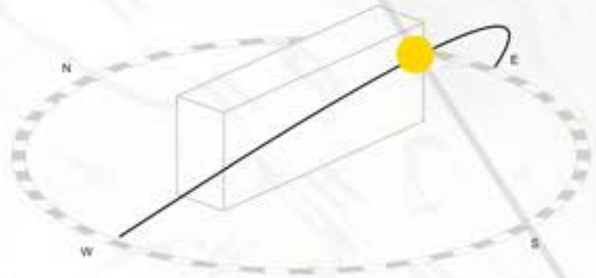
The premise of this thesis is to create a responsive screening device from the harsh and every changing sun. It is for that reason why looking at sun behavior and path is an essential research for the project. For sun analyzing we will look at major events that take place during a period of time. One being the period of time through the day and the other being a period of time throughout the year. For the day we have three major time events : morning, midday, and evening. In the morning it is usually acceptable to invite the sun into the building to warm up the space from the overnight temperatures. In the midday the earth's crust starts to heat up more, requiring the need to block some sun. Finally in the evening the environment around us is warm especially around 3 p.m. where it is the hottest time of the day. Now looking at annually we have the winter, summer and equinox solstices. For winter we want to allow sun into the space whereas in summer we want to block the intense sun rays. All of the events and outcomes will be presented into the design of the kinetic facade system to insure the most efficient responsive skin system.

Summer

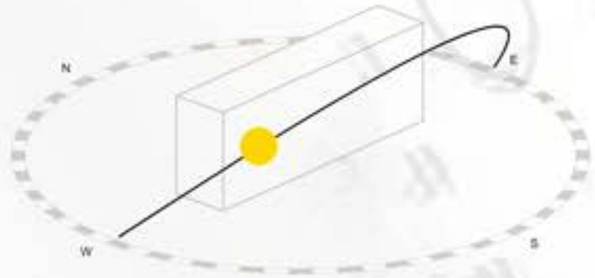
Morning



Midday

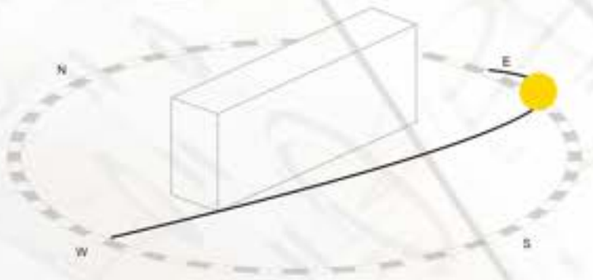


Evening

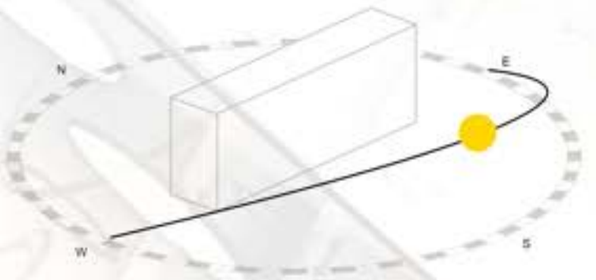


Winter

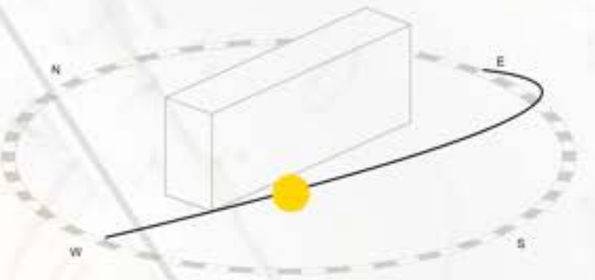
Morning



Midday



Evening

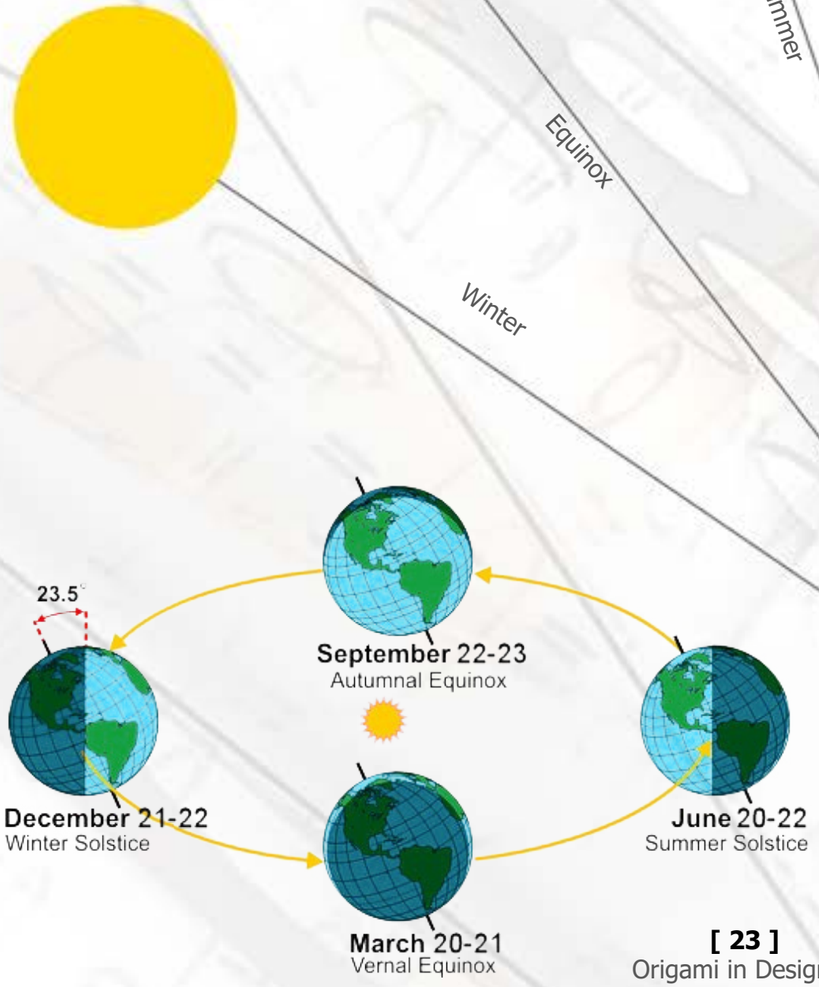


Our location of Atlanta Georgia is located at the Tropic of cancer line .This means that this area gets 13.5 hours of sunlight during the summer, winter, and equinox solstice.

For the summer solstice the sun is set at an angle of 23.5 degrees N of the Equator for the Tropic of Cancer area. For the winter solstice, the sun is set at an angle of 23.5 degrees S of the Equator for the Tropic of Cancer area.

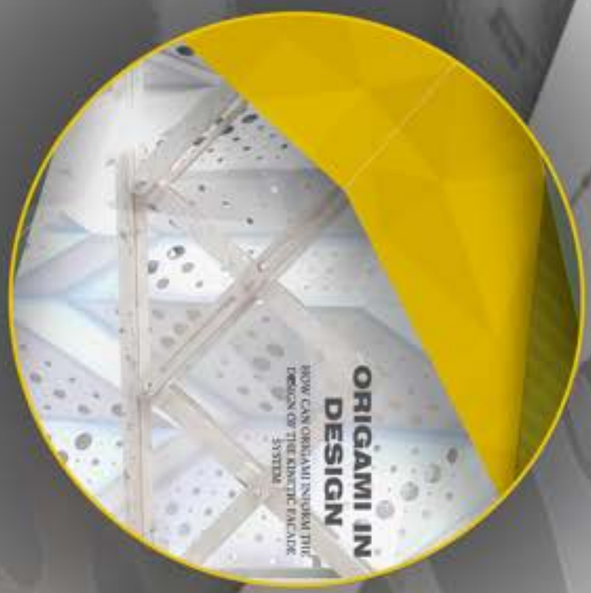
The temperatures of Atlanta range from 65 degrees in the morning up to 85 degrees in the evening for the summer times. For the winter the temperatures range from 36 degrees in the morning to 55 degrees in the evening. (WeatherSpark, 2022).

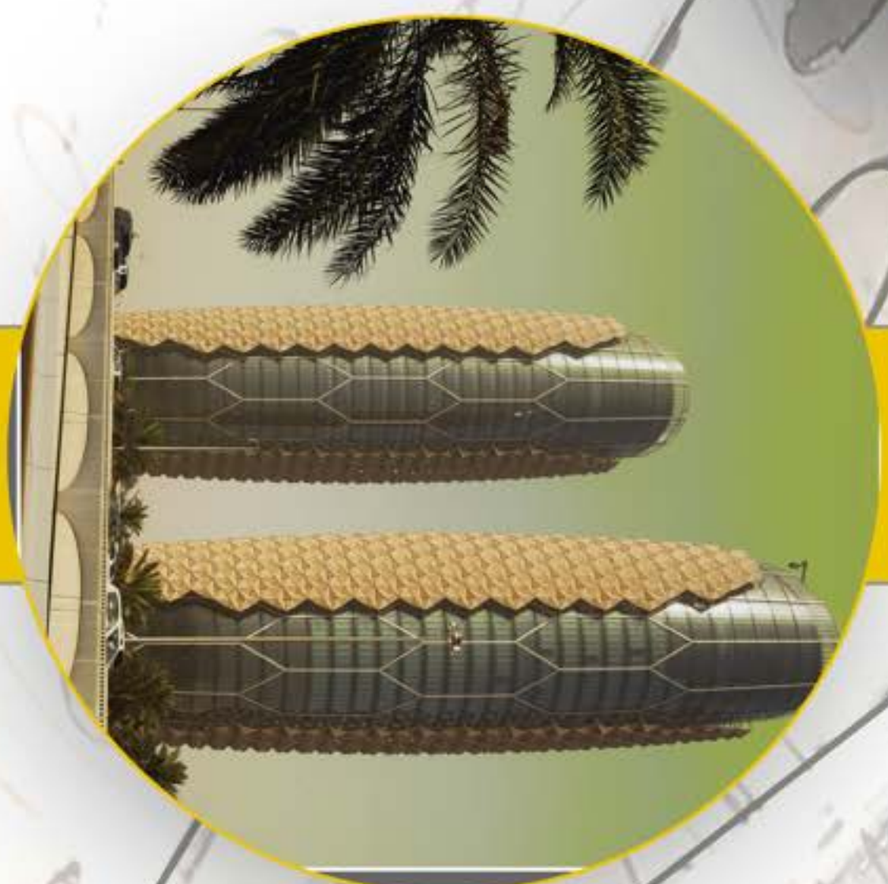
[22]


23.5°
September 22-23
Autumnal Equinox
December 21-22
Winter Solstice
June 20-22
Summer Solstice
March 20-21
Vernal Equinox

[23]


Summer
Equinox
Winter





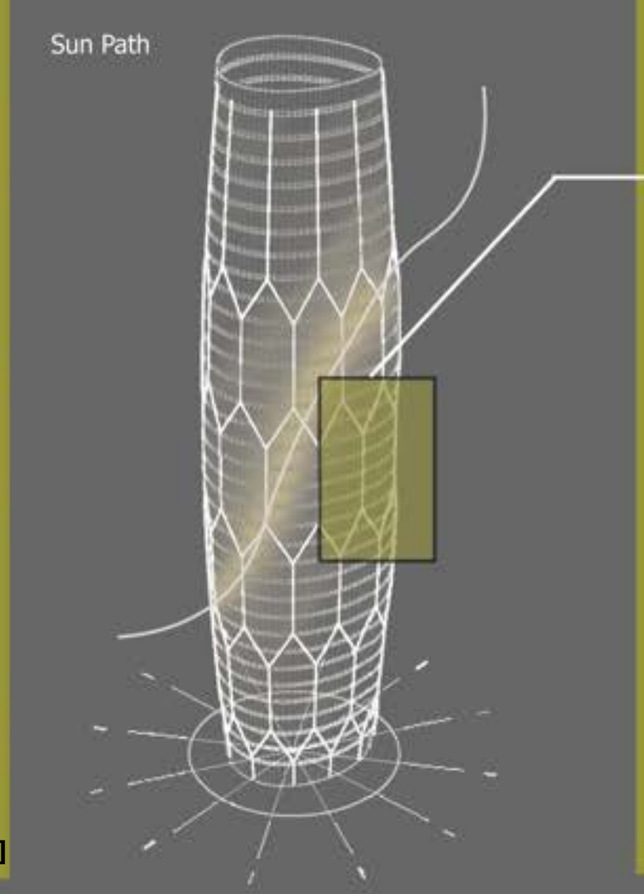
Chapter 3
Precedents


ity Architecture Building

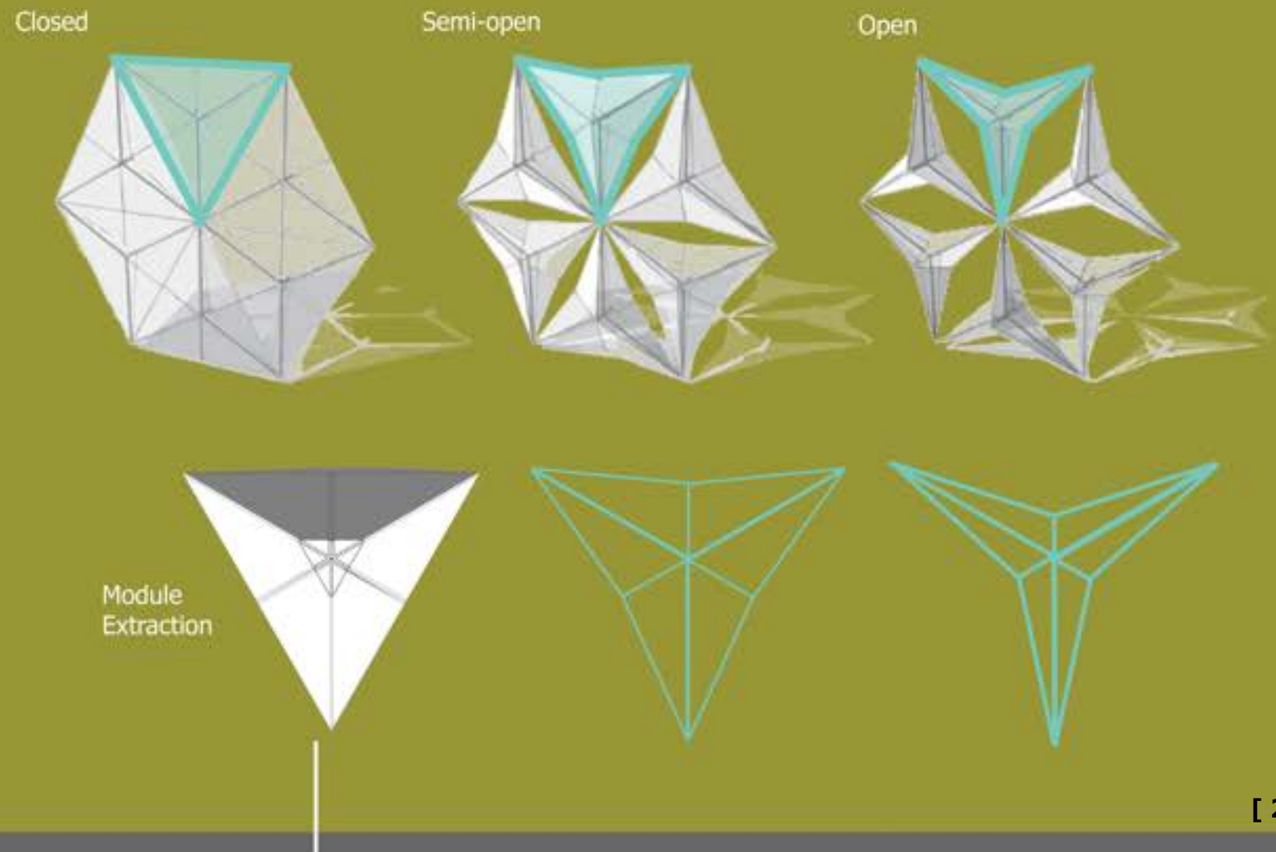
Al Bahr Towers

The Al Bahr Towers is a high rise structure in Abu Dhabi and is today's largest sun responsive tower. As for the design concept of the tower it is based on the fusion of cultural/regional architecture and performance based technology,(ahr.co.uk). The skin is an origami type style of lattice-work which consists of wood/metal to create a movement of opening and closing to the harsh Abu Dhabi conditions. The skin design is very simple and modular for easy assembly and makes the tower energy efficient and effective for a climate responsive facade. It becomes inherently useful when the sun's movement is unavoidable, "As the sun rises in the morning in the east, the mashrabiya along the east of the building will all begin to close and as the sun moves round the building, then that whole vertical strip of mashrabiya will move with the sun," said Peter Oborn,(Archdaily). This is a great example of using origami kinetic systems as an exterior facade system.

[25]



[28]



[29]

[26]

[27]

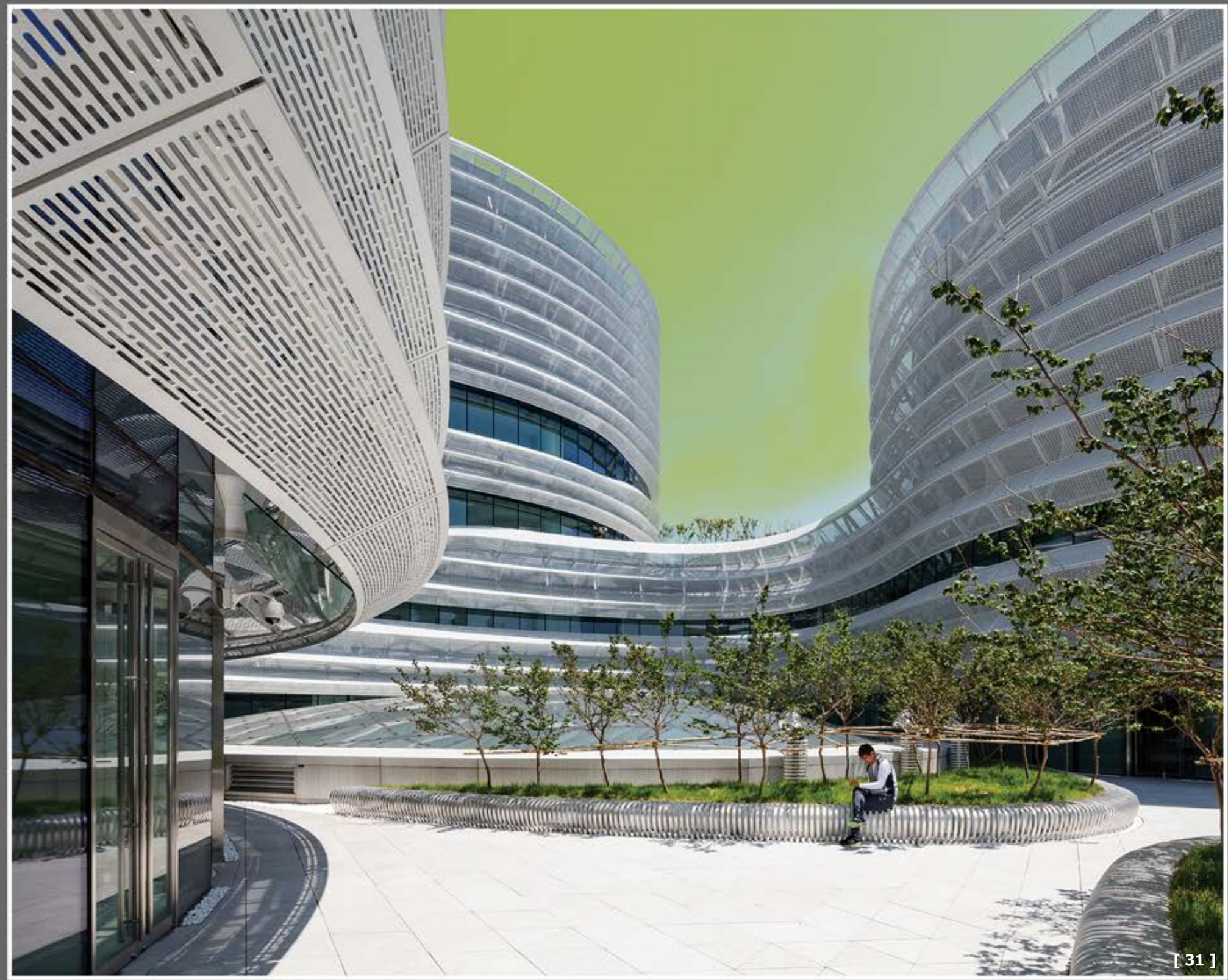
As mentioned, the facade is supposed to help with solar gain, with this particular design, the screen is said to have reduced the solar gain by more than 50 percent and loosen the need for air conditioning, (Archdaily). As for 2012, the project was awarded the 2012 tall building innovation award for its performance based architecture and sustainability approach.

[30]

CJ Research Center Building

The CJ Research Center located in Seoul South Korea, uses an accordion base facade system to control the outside environment. The climate responsive facade helps to mitigate the effects of Korea's constant changing weather with the use of expanding the skin to shade the building. The building uses a retractable device to prevent solar glare around the structure with various amount of "folded sheets". A great example of the use of the accordion based origami style.

The facade system of the research center focuses on " exposure " for direct sun and daylighting. Allowing the building to open and close when needed to sustain human comfort and energy reduction.



1
Extended Position

2
Retracted Position

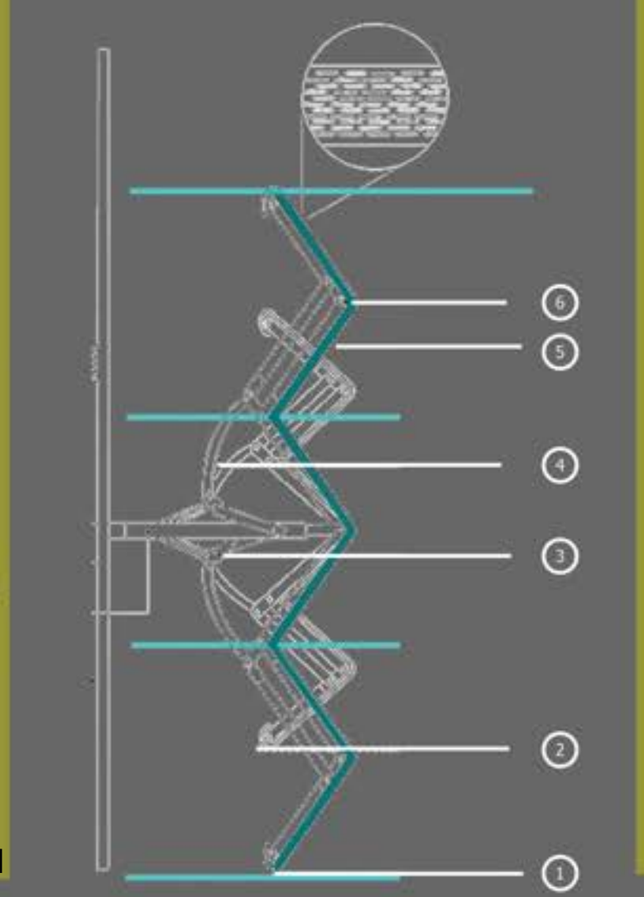
3
Linear Actuator-
System for kinetic
movement

4
Mechanical arms-
desing load for
allowing the push and
pull for facade

5
Pleated Membrane

6
Folding mechanism-
Origami system

As for the material and origami format, it uses aluminum panel sheets with perforations that lay out on the machanism to act as an accordion.



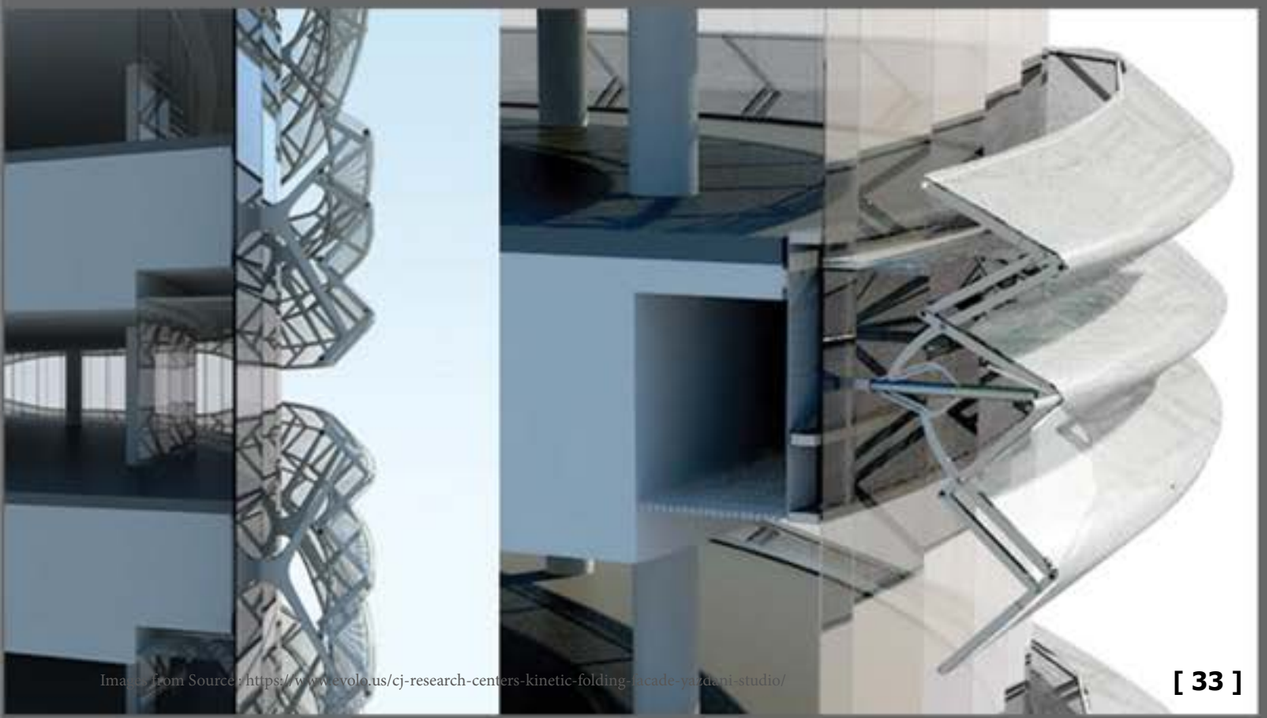
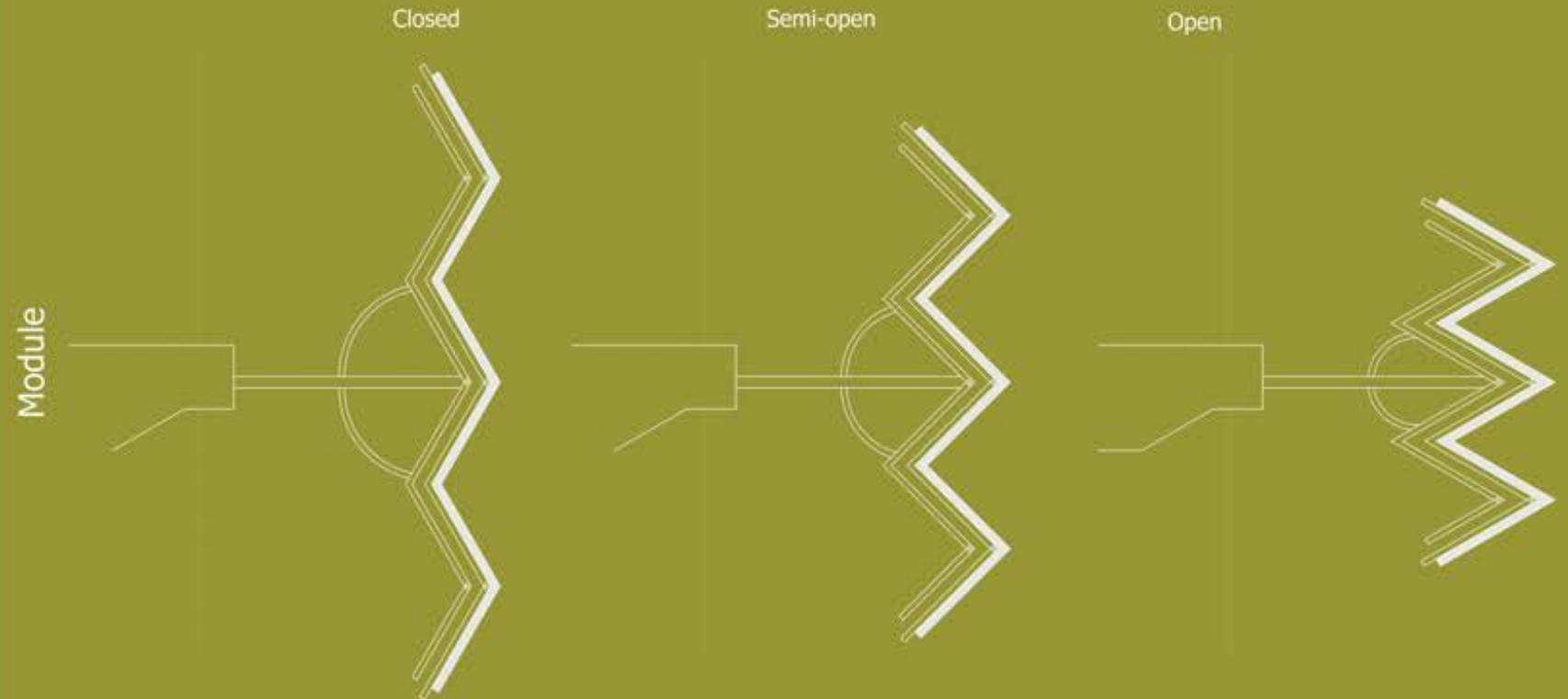
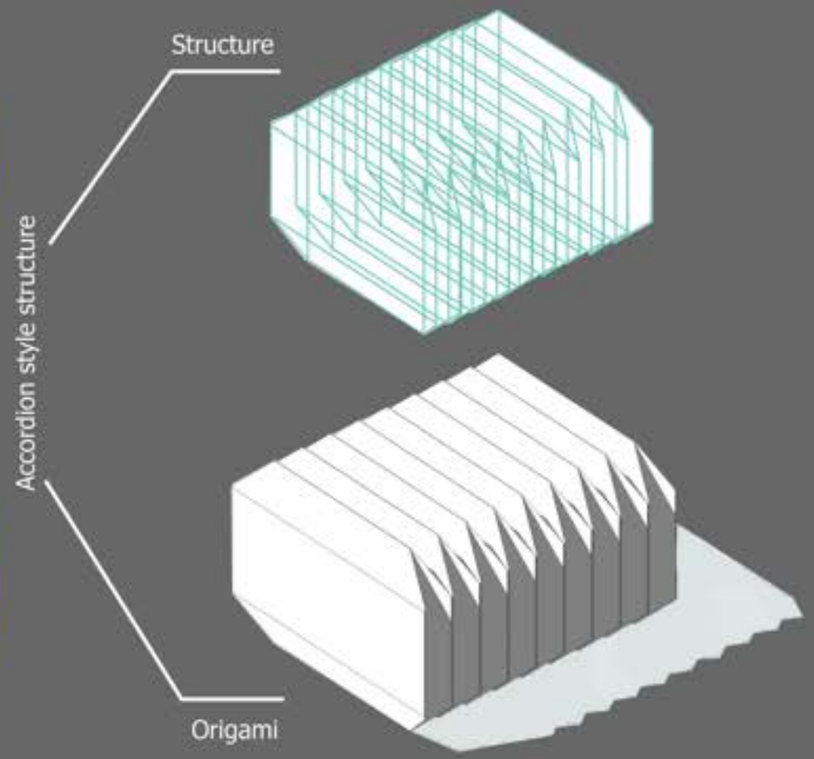


Image from Source: https://www.evolo.us/cj-research-centers-kinetic-folding-facade-yazdani-studio/





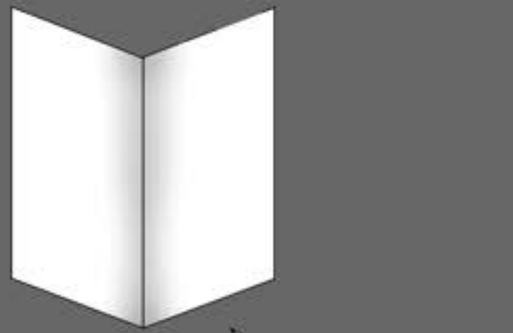
The Syddansk Universitet communications and design building

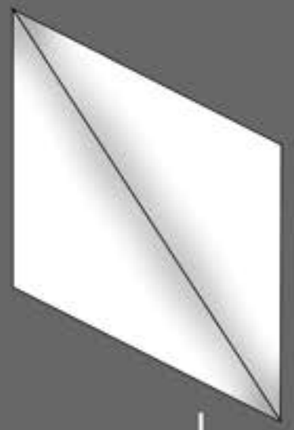
The Syddansk Universitet communications and design building uses simple folding techniques to optimize efficient daylighting to the structure. The folds and facade are motor based controlled and are censored to change when needed less or more daylighting. This system also prevents large sun glare and sun gain to the building. Archdaily states "The daylight changes and varies during the course of the day and year. Thus, Holding Campus is fitted with dynamic solar shading, which adjusts to the specific climate conditions and user patterns and provides optimal daylight and a comfortable indoor climate spaces along the facade"(Archdaily). It expresses great beauty to the exterior and comfortability to the interior.

closed

Semi-open

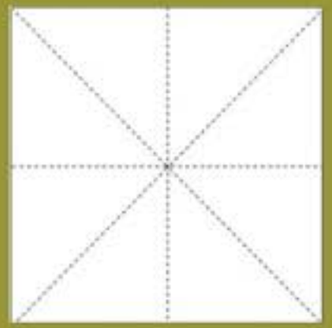
Open

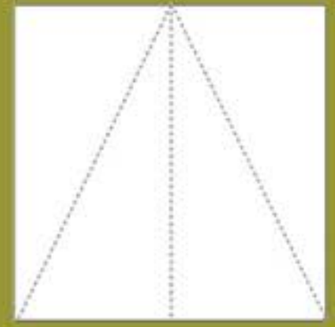




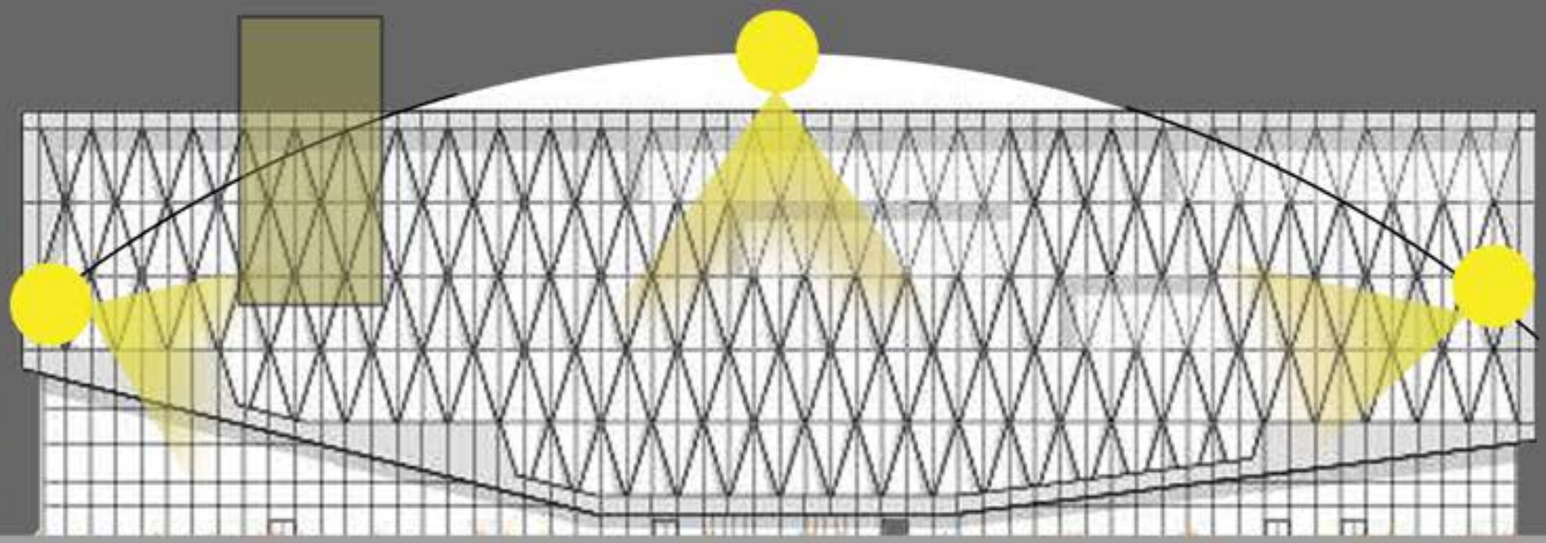
Module

All modules cut from the same sheet





The square module is a simple folding technique of folding a square sheet into different folds. These folds are than raised to create a "butterfly effect".




ORIGAMI IN
DESIGN
HOW CAN ORIGAMI INFORM THE
DESIGN OF THE KINETIC FACADE
SYSTEM

Chapter 4
Site Introduction

Kennesaw State University Architecture Building

Kennesaw State University, Marietta Caqmpus, N - Buidling
1100 S Hornet Dr, Marietta, GA 30060
Specific site - The south and west facing sides of the building envelope
In this thesis, my siter will be a representation of the KSU architecture building. Where I take the south facing structure and extrude its height for more analytics and proveide windows to the west facing wall.
Existing conditions- The building has horizonatal louvers and double glazing curtain wall. The south face is broken up with an armature and aluminium mullions.

Strength of Site

The site allows me to compare and contrast traditional passive strategies. Such as the horizonantal fins on the existing site conditions.

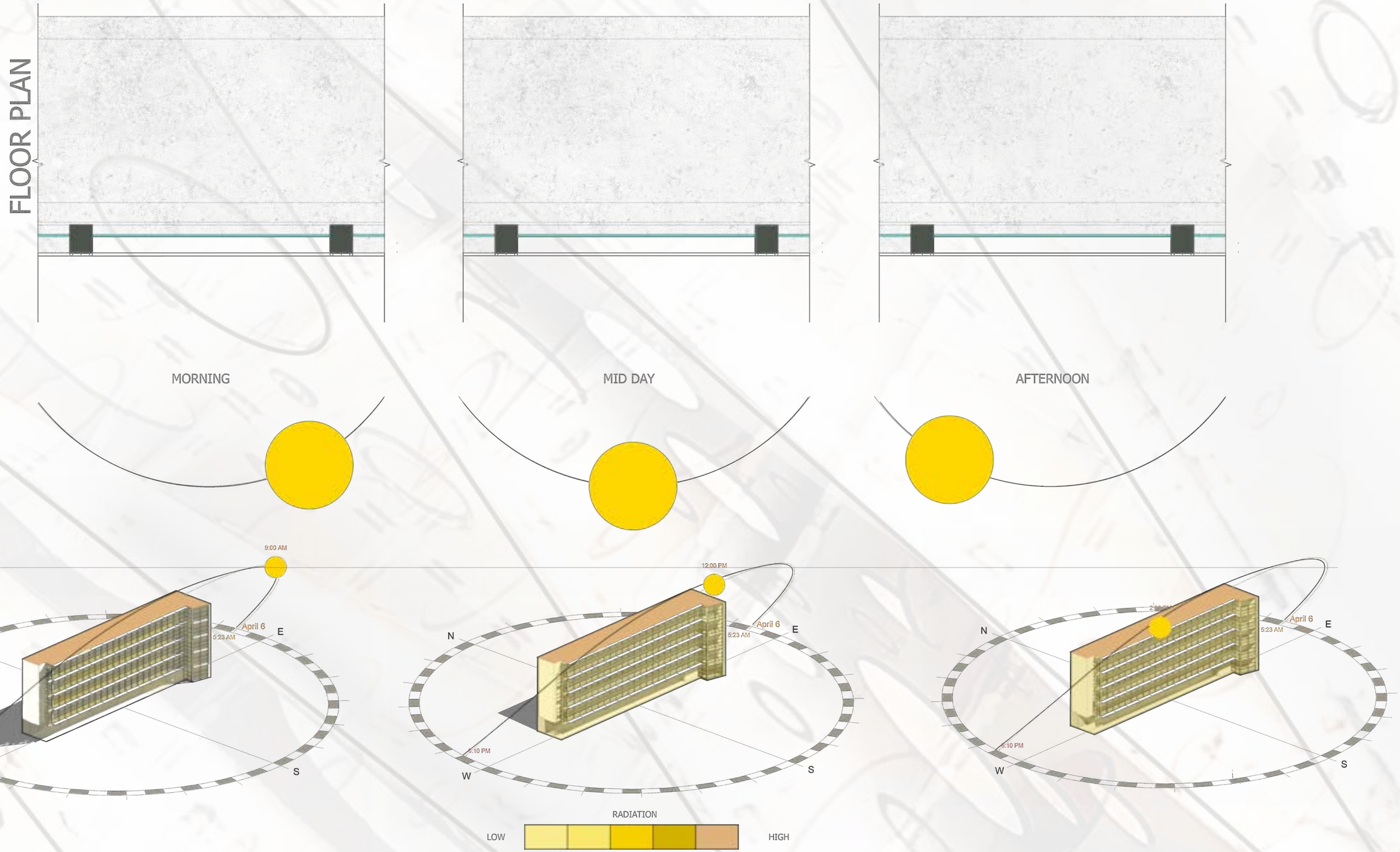
The building almost faces true south. Which in this case is exceptional because we want to account for that harsh facing wall when it comes to direct sun gain.

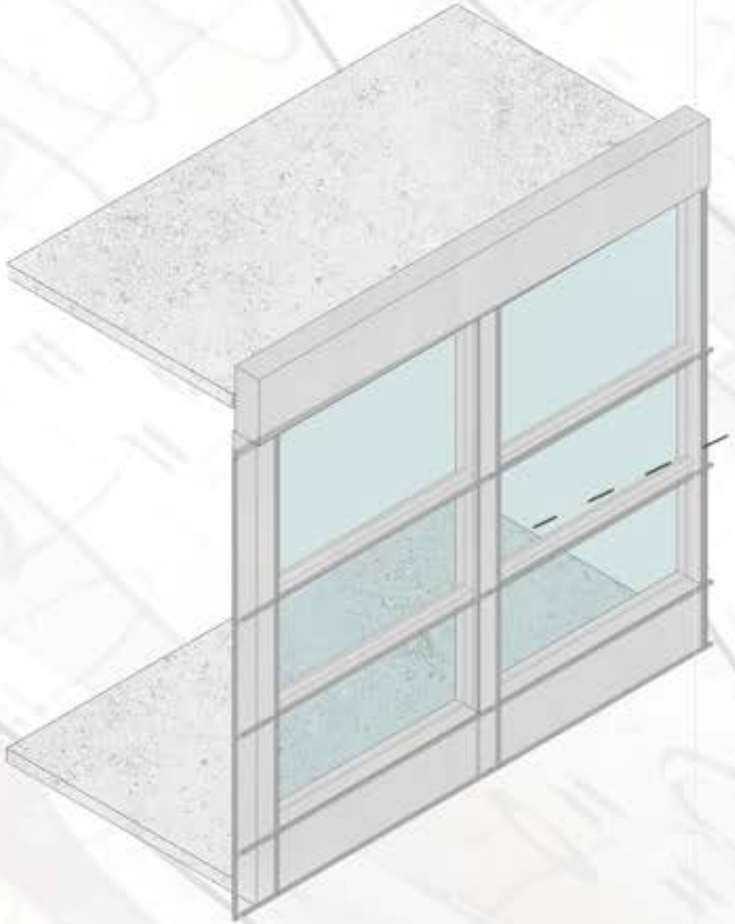
I am very aware of the building conditions and the heating and cooling that takes place to maintain the building year round.

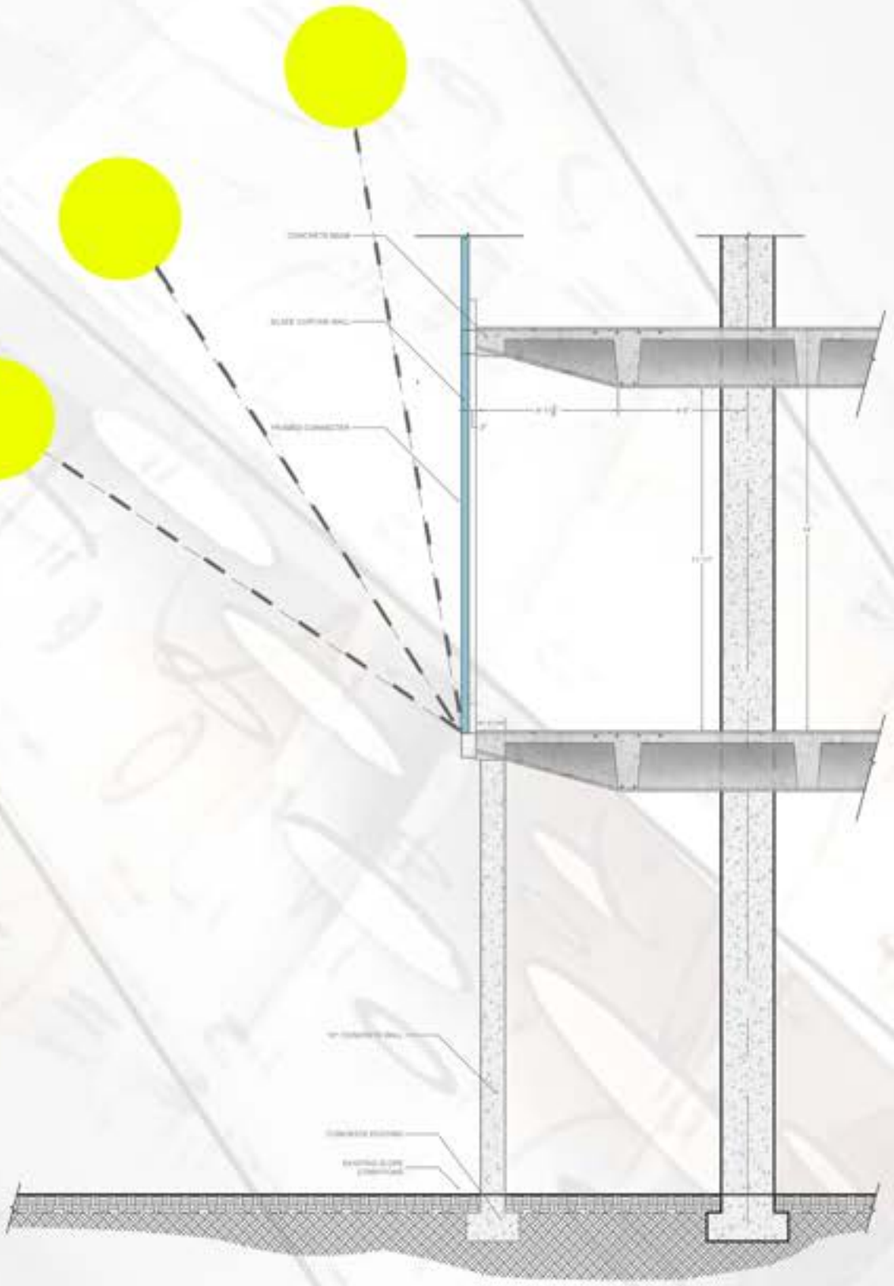
Weakness of Site

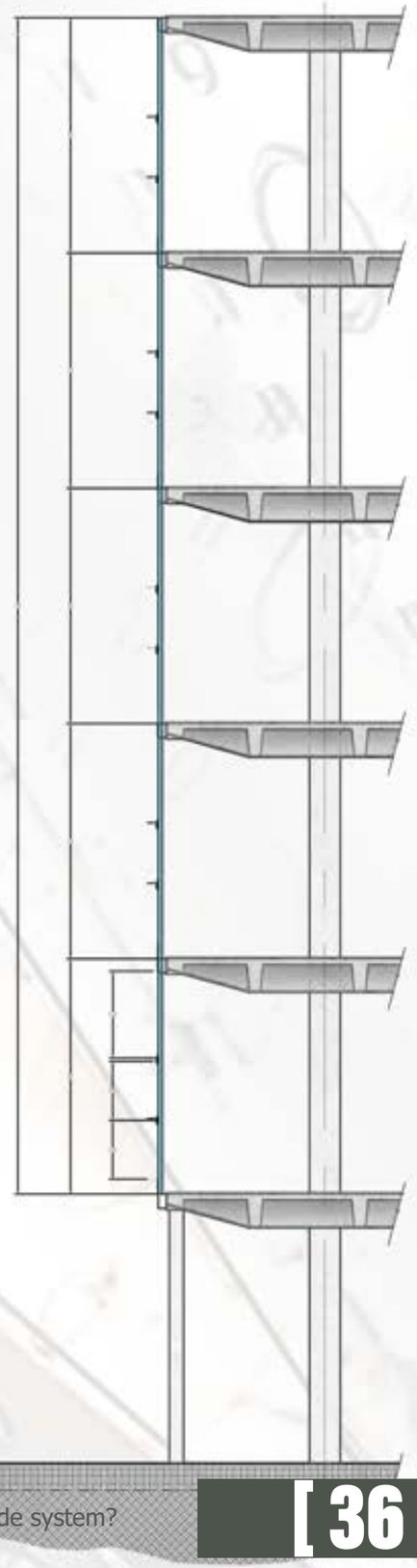
I want to explore the best and worse case scenario and on this building, the west facade has no glazing. But for exploration, I will act upon as if they were windows on the west facing side.

Solar of site









The sun is as follows, where in the morning temperatures range from 60 to 70 degrees where the building is in need of heating up. The midday temperatures is around on average 75 degrees. And finally in the evening, the temperatures range from 80 to 90 degrees especially around 3pm where the earth is the hottest. This moment is where the origami will become clear in blocking the direct sun.

As mentioned, this building's glazing wall is heavily directed towards the south, so looking at the sun studies of each part of the day is critical to our design.

Large portion of this thesis focuses on the site's "bays". These bays is where the origami system will be implemented and then fabricated throughout the entirety of the building.


ORIGAMI IN
DESIGN
HOW CAN ORIGAMI INFORM THE
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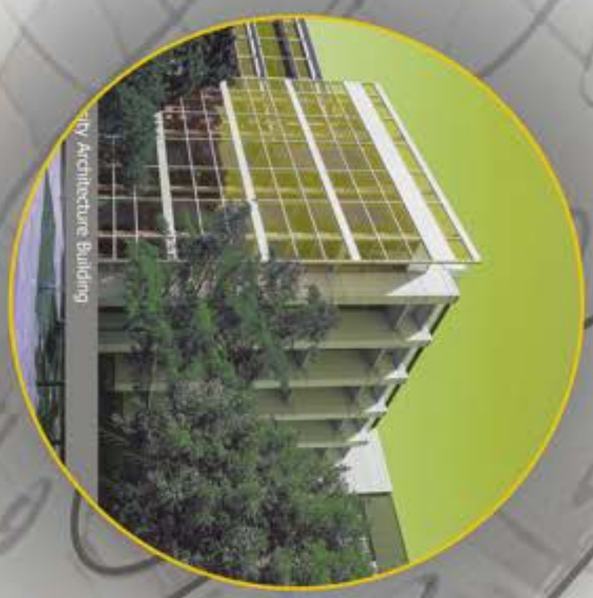
SYSTEM



Chapter 5
Design and Application

ORIGAMI IN DESIGN

HOW CAN ORIGAMI INFORM THE DESIGN OF THE KINETIC FACADE SYSTEM?

INTRODUCTION

WITH 40 PERCENT OF THE 75 PERCENT ANNUAL GLOBAL GREENHOUSE EMISSIONS COMING FROM BUILDING OPERATIONS (ARCHITECTURE 2030), WE AS DESIGNERS MUST SHIFT FROM A FORMAL TO A PERFORMANCE-BASED ARCHITECTURE. AN ARCHITECTURE THAT INSTINCTIVELY ADDRESSES REDUCED ENERGY CONSUMPTION AND THEREFORE LOWER CO_2 EMISSIONS THROUGH THE INTEGRATION OF PASSIVE DESIGN STRATEGIES. IN ORDER TO COMPETE IN A FUTURE WITH CO_2 REDUCTION, WE MUST ADDRESS BUILDING PERFORMANCE.

THIS THESIS WILL EXAMINE ORIGAMI'S FOLDING TECHNIQUES AND ITS KINETIC POTENTIAL WITHIN THE INTEGRATION OF AN ARCHITECTURAL FACADE SYSTEM. THE GOAL IS TO CREATE A CLIMATE RESPONSIVE FACADE SYSTEM THAT NEGATES THE USE OF ENERGY WHILE PROVIDING A BETTER BUILDING PERFORMANCE.

QUESTIONS

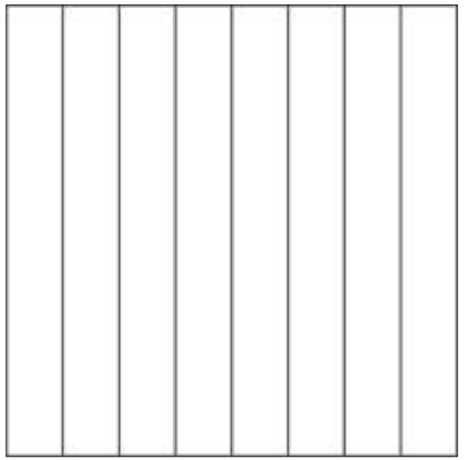
CAN ORIGAMI PROVIDE THE NECESSARY PERFORMANCE OF ARCHITECTURE BOTH VISUALLY AND TECHNICALLY?

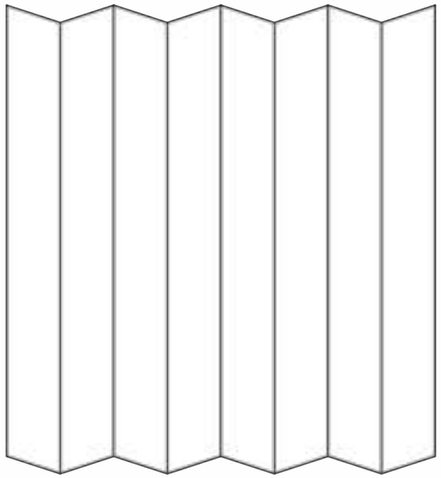
CAN AN ORIGAMI INSPIRED SCREENING DEVICE BE DESIGNED TO KINETICALLY SHADE A BUILDING AND THEREFORE DECREASE ITS ENERGY CONSUMPTION AND INHERENTLY NOT AFFECT CO_2 EMISSIONS?

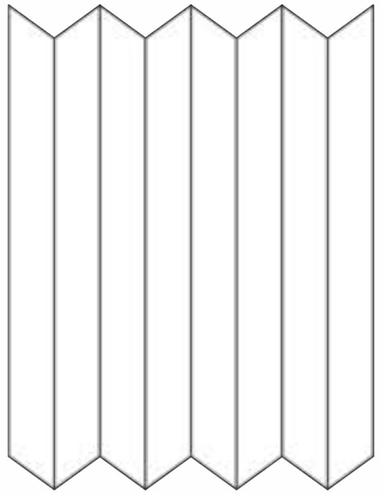
RESULT

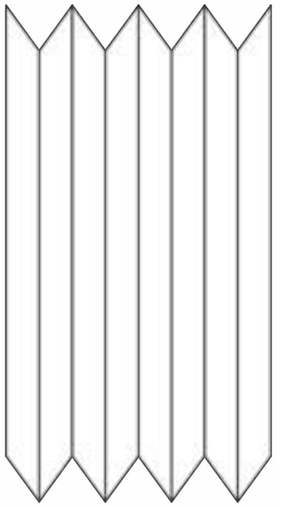
THE RESULT OF THE THESIS WILL BE A SCALED ORIGAMI SYSTEM THAT WILL THEN BE EMPLOYED IN A DESIGN PROJECT AND ULTIMATELY BE APPLIE TO REAL WORLD APPLICATIONS.

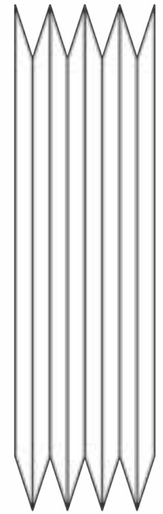
Why? . . . Because of origami's adaptablity and ability to collapse and expand.



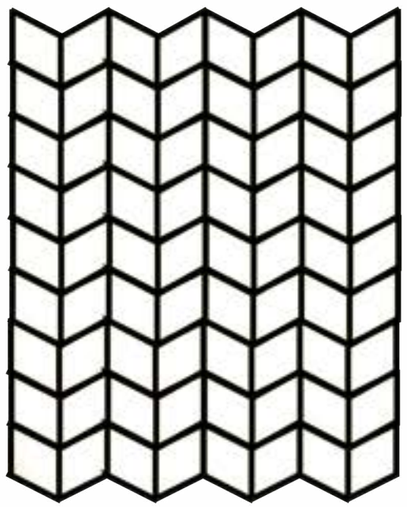


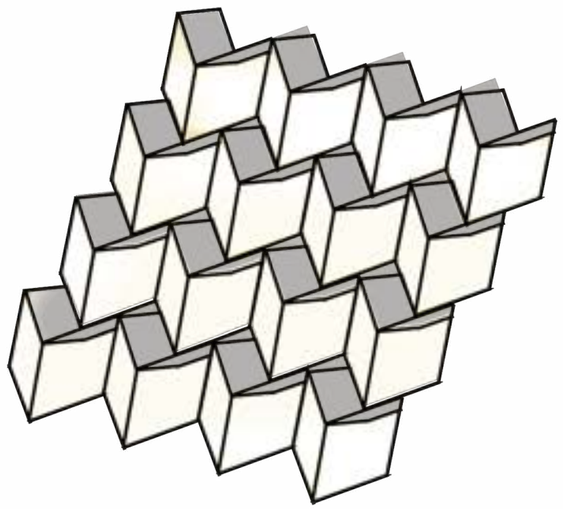


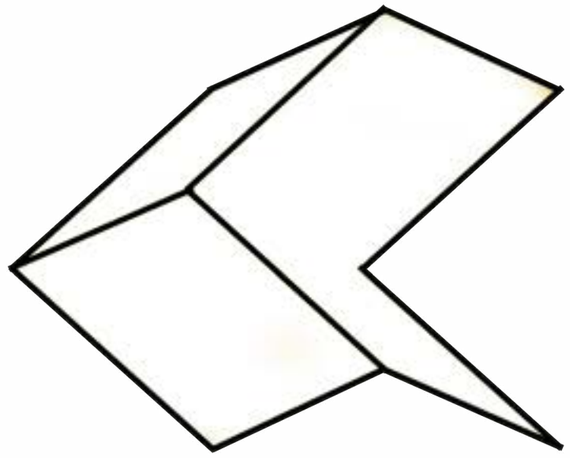




What? . . . Miura Ori fold, taking advantage of the valley and mountain pattern.



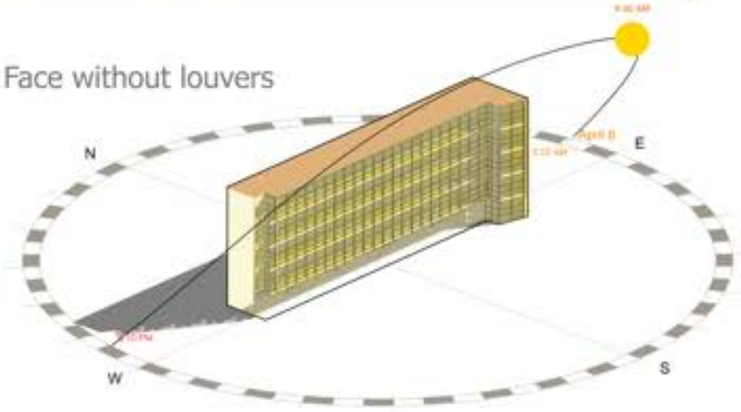




How? . . . With the use of kinetics, linear actuator.

Sun Analysis

South Face without louvers

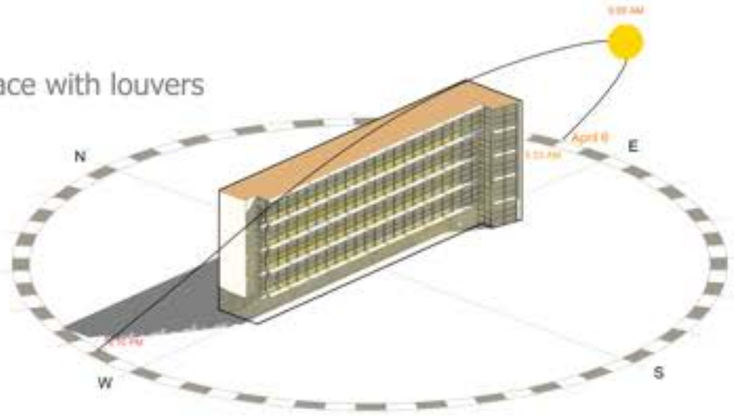


MORNING

In the morning, the sun intensity is much less than other parts of the day and average temperatures range from 65 to 70 degrees in the areas of Altanta, Georgia.

Without louvers, the building's window surface area of 89 SF absorbs 50% of the solar gain or 2.3(m) x 2.1(m) x .025(m) x 141 = 17 BTU

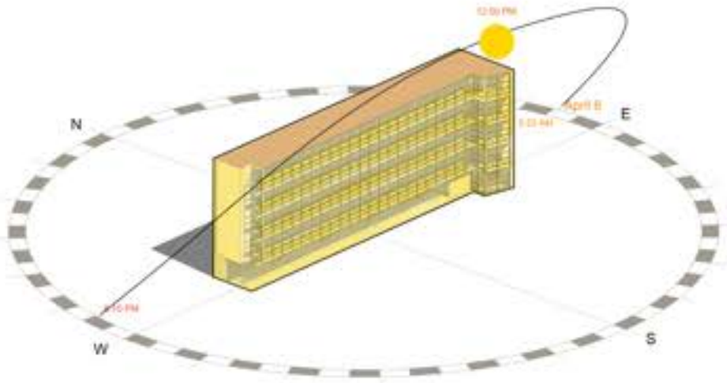
South Face with louvers



MORNING

As noted, for the morning solar gain without louvers the BTU was 17,

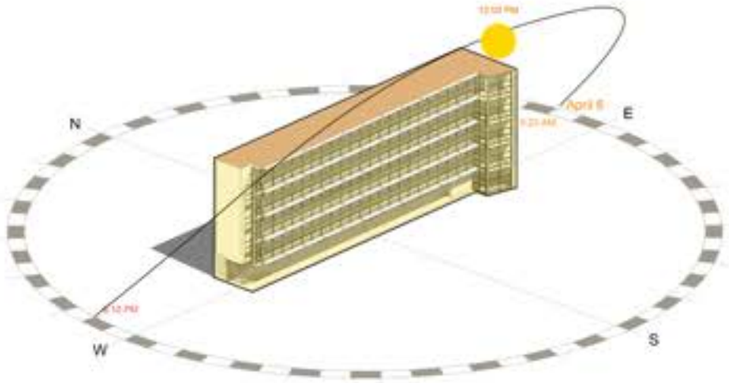
With louvers, the building's window surface area of 89 SF absorbs 30% of the solar gain or 2.3(m) x 1.4(m) x .025(m) x 141= 12 BTU



MID DAY

During the mid day, the sun intensity is averaged 75 degrees in the areas of Altanta, Georgia.

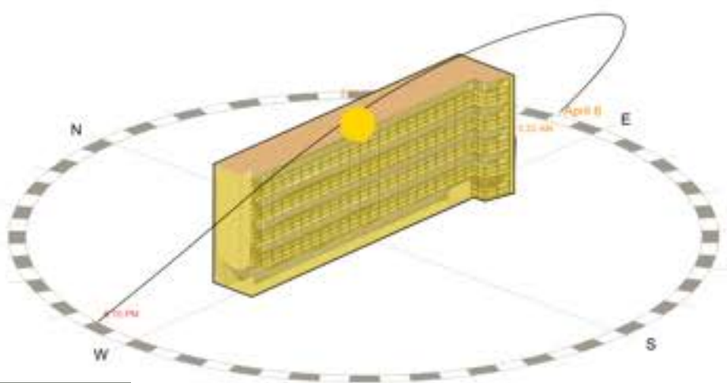
Without louvers, the building's window surface area of 89 SF absorbs 60% of the solar gain or 2.3(m) x 2.6(m) x .025(m) x 141 = 21 BTU



MID DAY

As noted, for the mid day solar gain without louvers the BTU was 21,

With louvers, the building's window surface area of 89 SF absorbs 40% of the solar gain or 2.3(m) x 1.7(m) x .025(m) x 141= 14 BTU

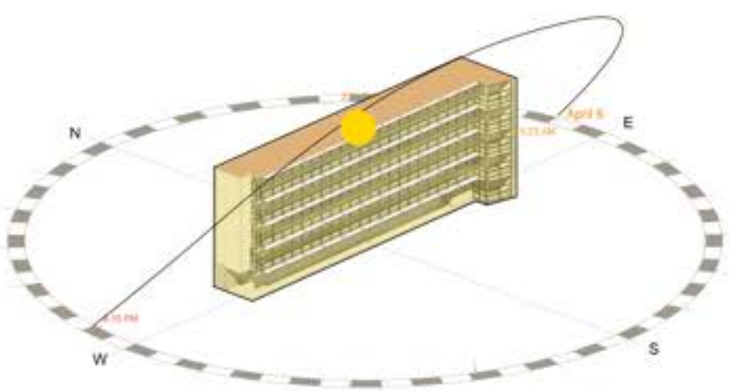


EVENING

In the Evening, the sun intensity is the highest and averages temperatures from 80 to 90 degrees in the areas of Altanta, Georgia.

Without louvers, the building's window surface area of 89 SF absorbs 65% of the solar gain and with the Earth's heated crust makes the heat feel even worse

With 2.3(m) x 2.7(m) x .025(m) x 141 = 22 BTU



EVENING

As noted, for the evening solar gain without louvers the BTU was 22,

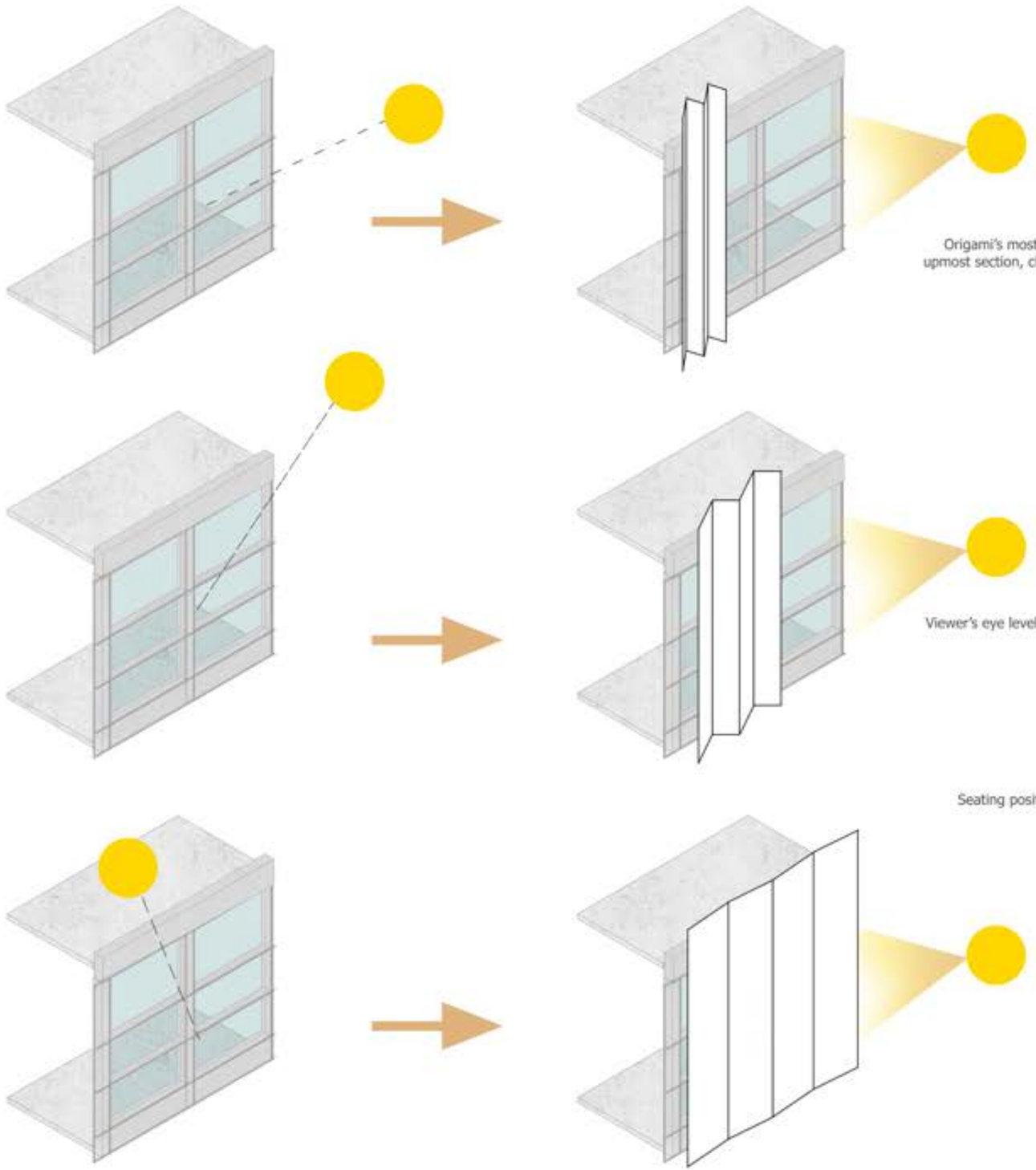
With louvers, the building's window surface area of 89 SF absorbs 45% of the solar gain or 2.3(m) x 1.9(m) x .025(m) x 141= 15.5 BTU

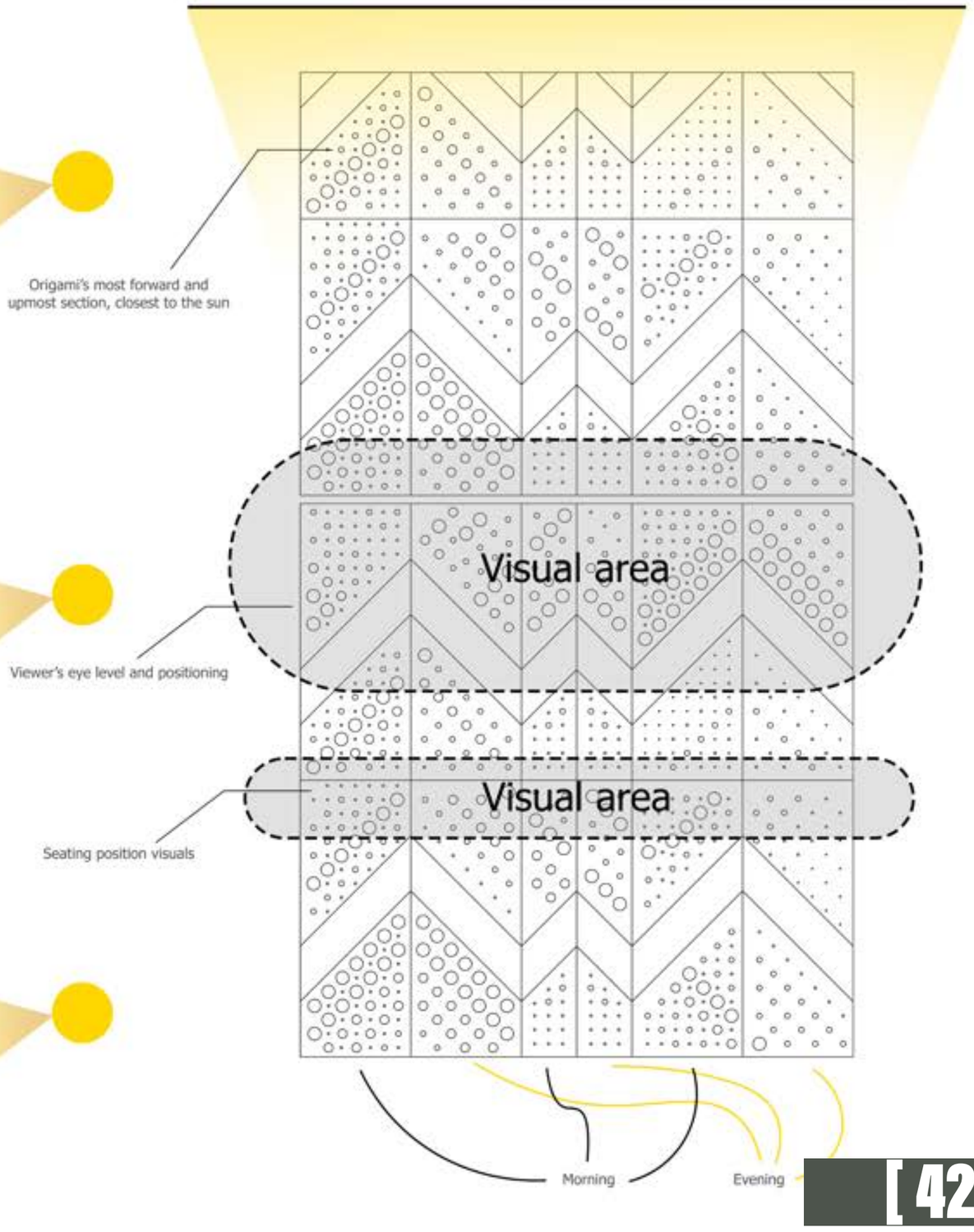
RADIATION

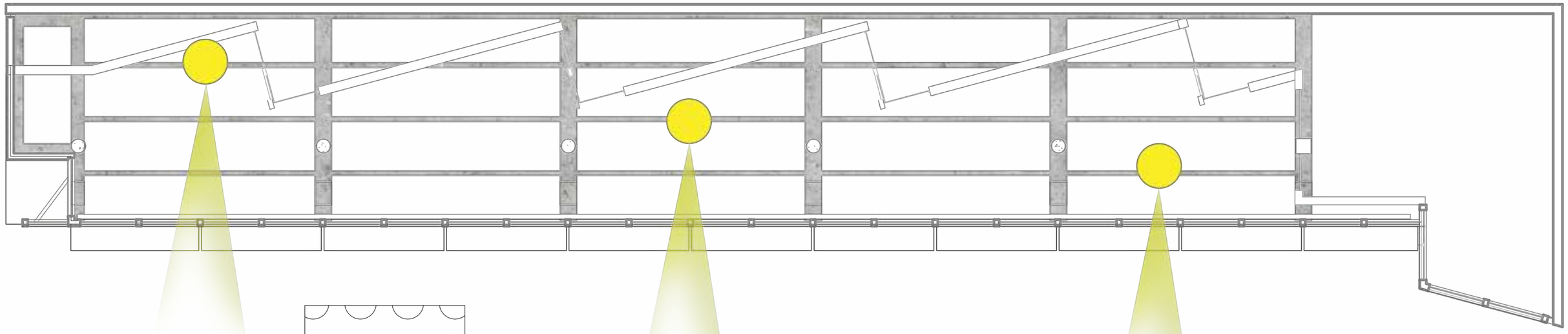
LOW HIGH

RADIATION

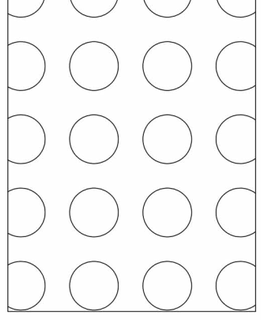
LOW HIGH



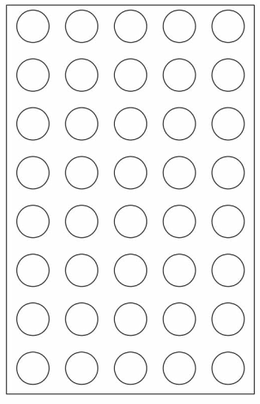

Origami's most forward and upmost section, closest to the sun
Viewer's eye level and positioning
Seating position visuals
Visual area
Visual area
Morning
Evening



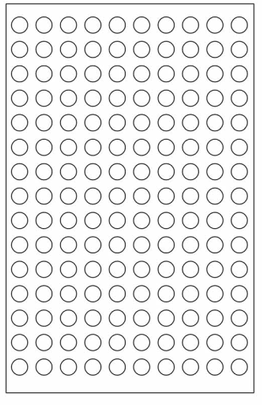
The perforations highly depend on distance of view. For 15 feet, the perforation size is efficient at 4” Diameter and 2” spacing. Leaving a block/view ratio of 62.5%



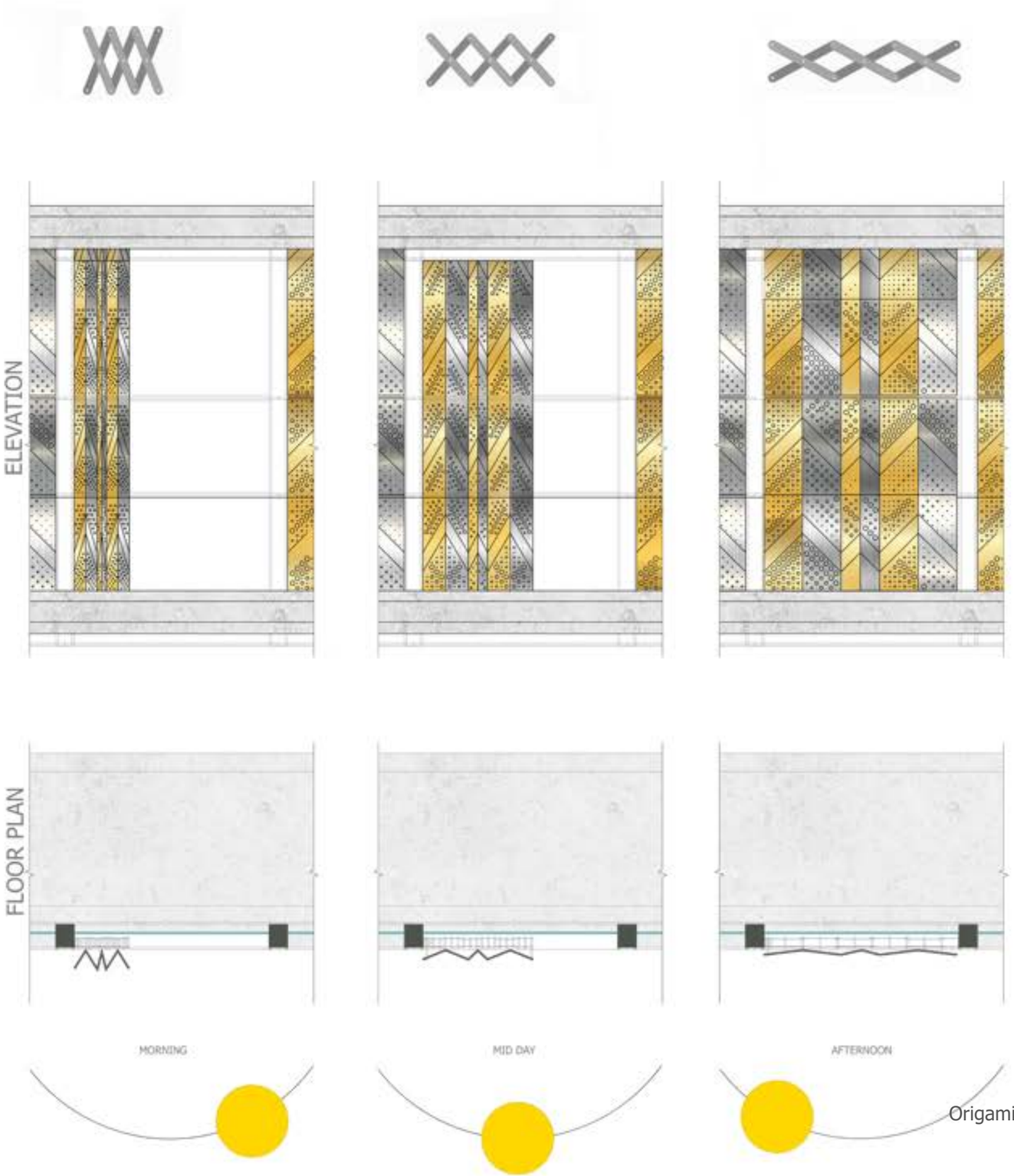
For 8 feet, the perforation size is efficient at 2” Diameter and 1” spacing. leaving a block/view ratio of 60%

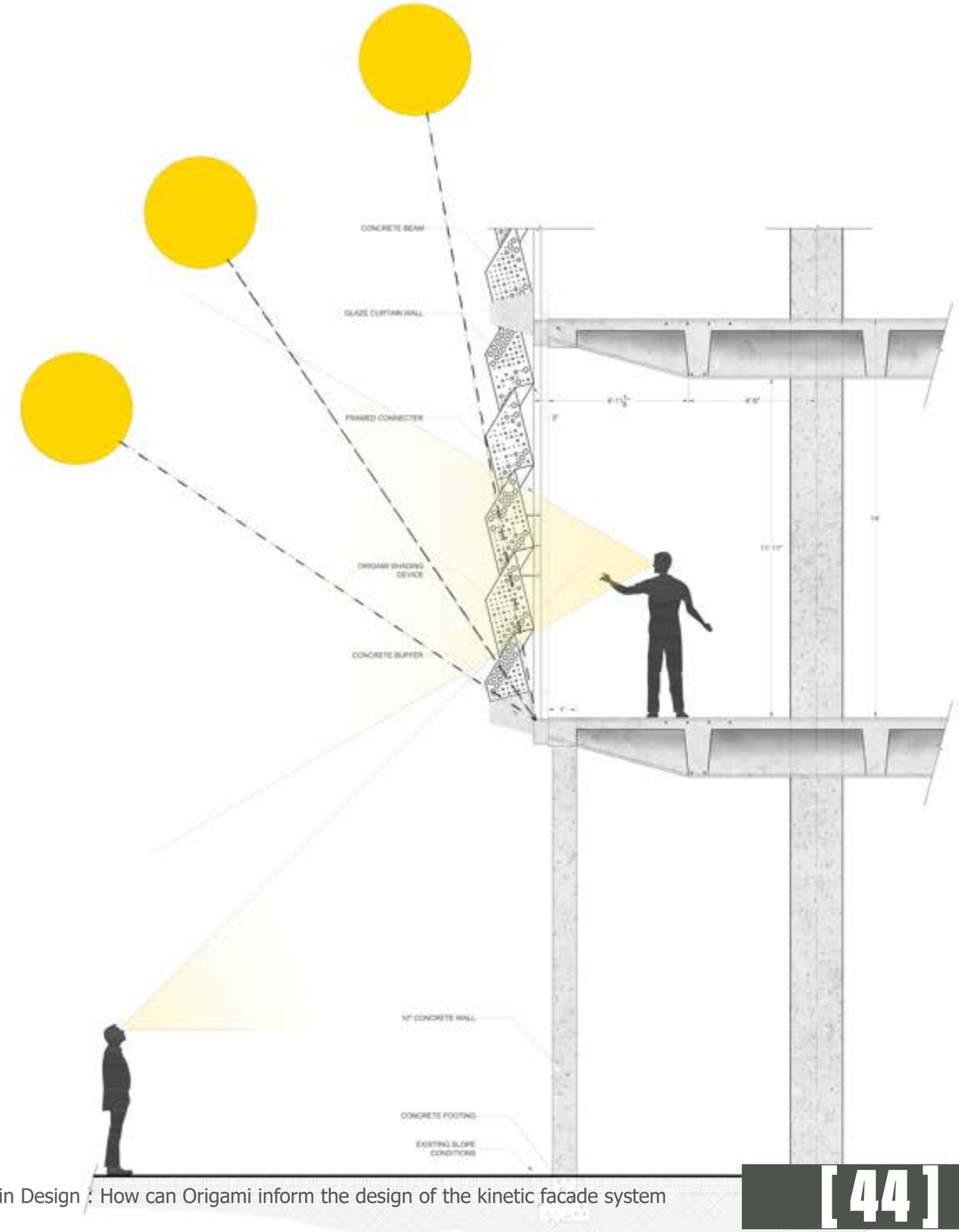


For 3 feet, the perforation size is efficient at 1” Diameter and 3/4” spacing. Leaving a block/view ratio of 67.5%

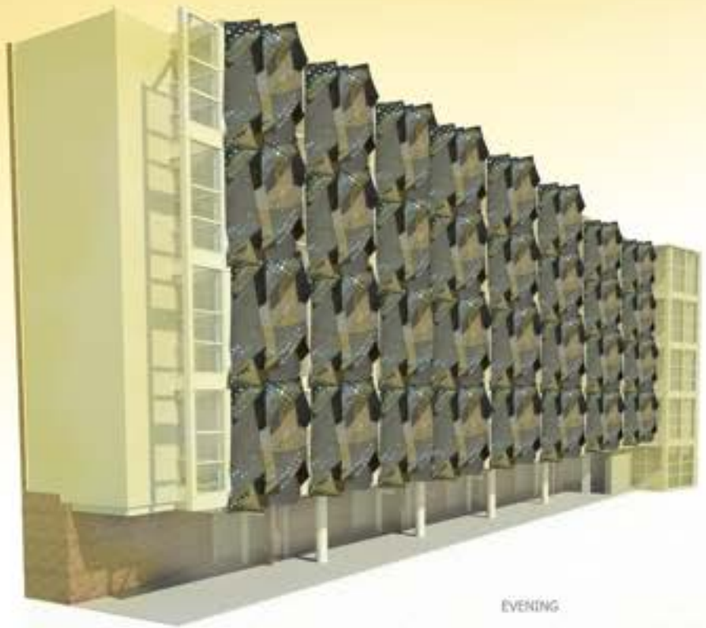


Application





Cove Tool Analysis



EVENING

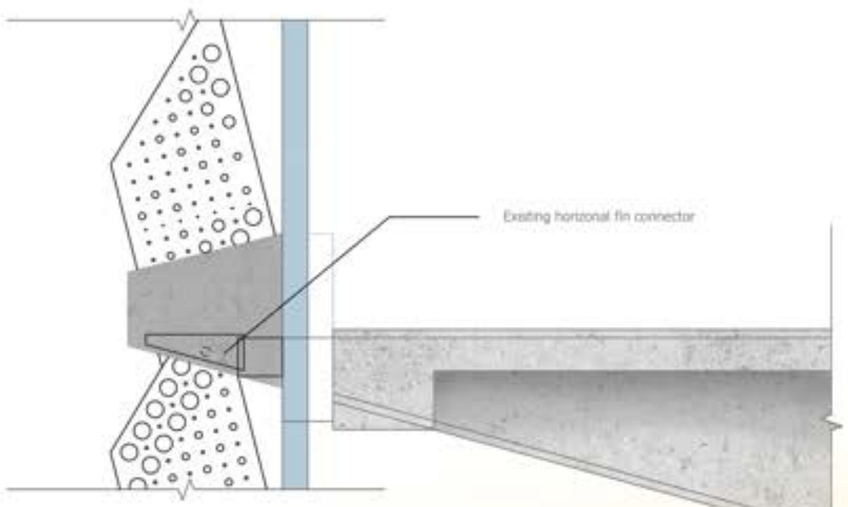
With Origami, the building's window surface area of 89 SF absorbs 24% of the solar gain or 1.58(m) x 1.24(m) x .025(m) x 141 = 7 BTU

MID DAY

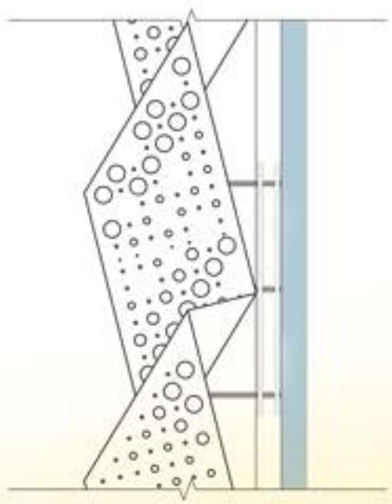
Without louvers, the building's window surface area of 89 SF absorbs 50% of the solar gain or 1.1(m) x 4.2(m) x .025(m) x 141 = 10 BTU

MORNING

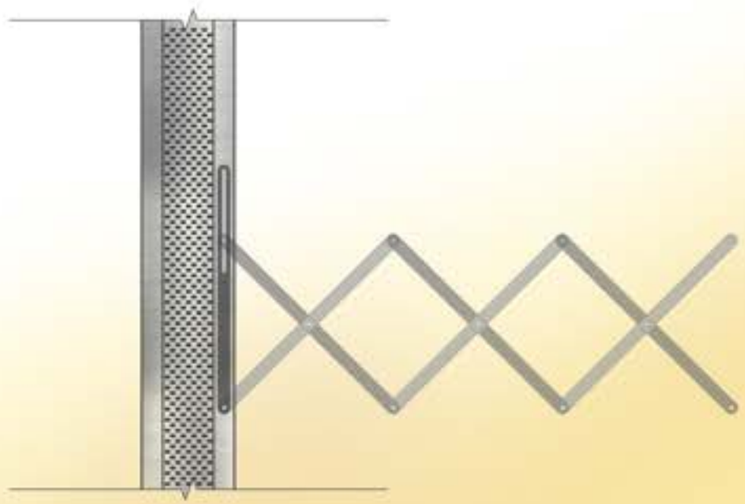
Without louvers, the building's window surface area of 89 SF absorbs 60% of the solar gain or 1.3(m) x 2.6(m) x .025(m) x 141 = 12 BTU



Using the existing conditions of the site, the origami facade can be integrated into the south facing wall.



The mechanism will be placed along side the bay's window mullion.



The scissor lift can then fully extend to the 7feet distance of the window bay.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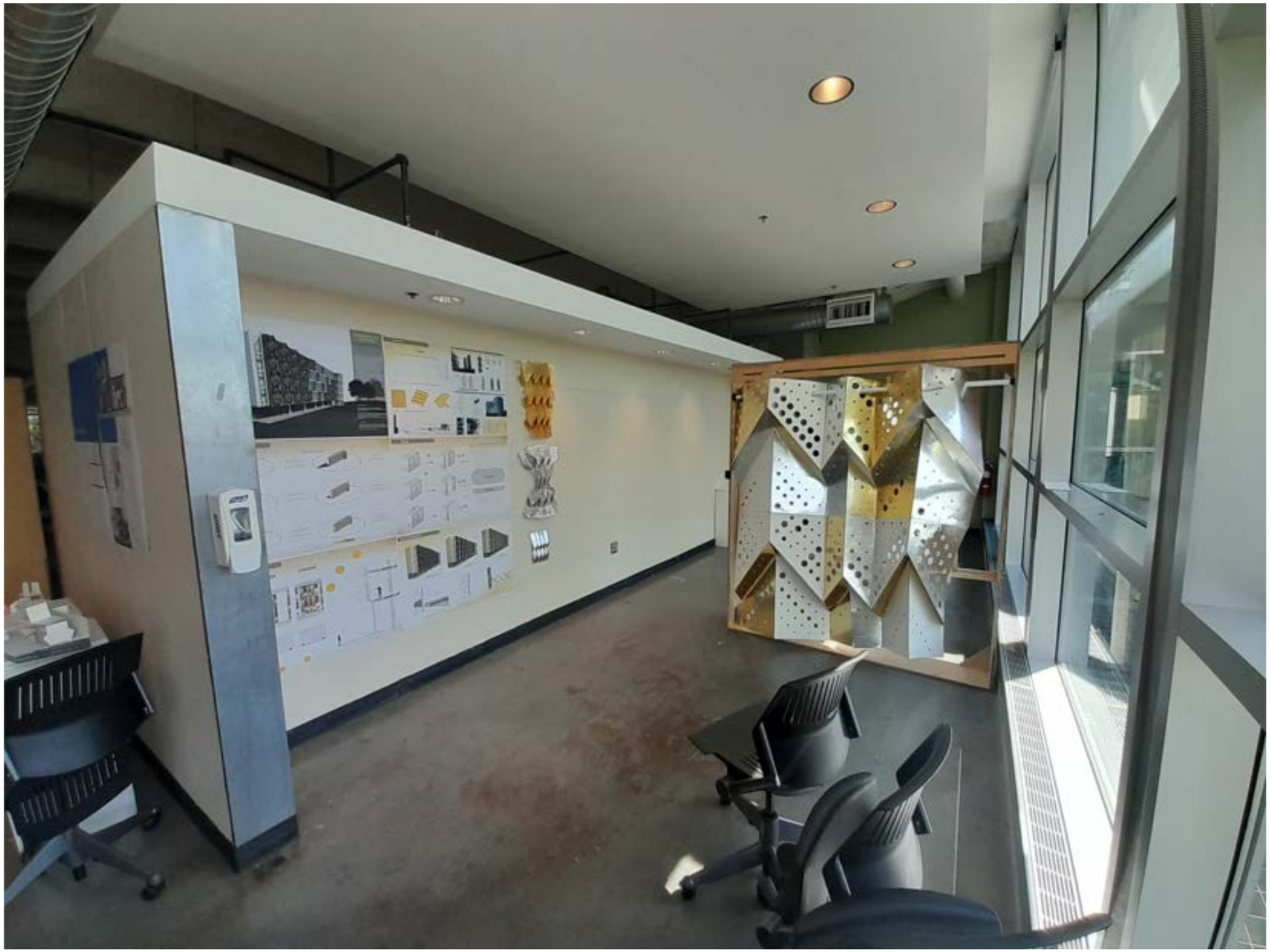
ORIGAMI IN
DESIGN
HOW CAN ORIGAMI INFORM THE
DESIGN OF THE KINETIC FACADE
SYSTEM

Chapter 6
Reflection

Reflection

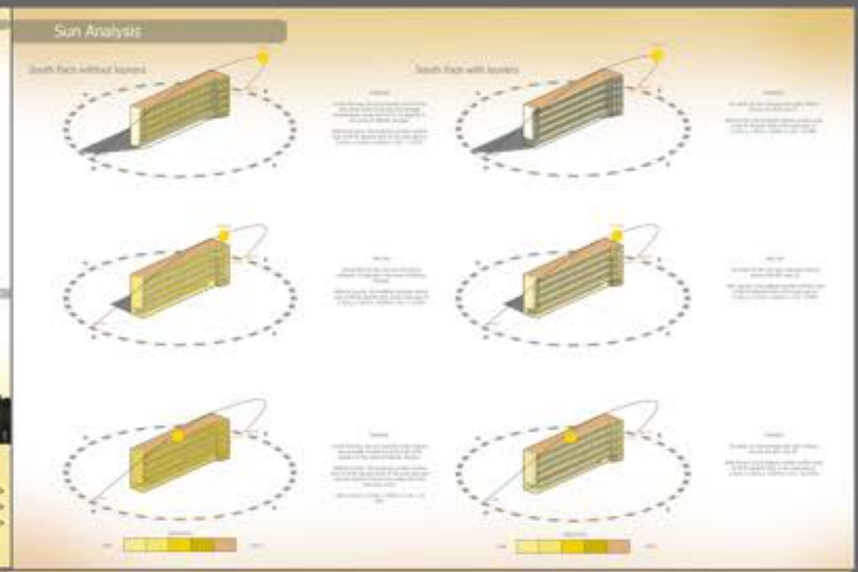
So in conclusion, the thesis explores all accounts for solar gain and expresses the efficiency of origami as a solar screening device. For our site of the architecture building we can see a 70 percent increase in cooling from the origami facade. Maintaining the buildings passive strategy instead of relying on heating and cooling will ultimately reduce co2 emissions. We can also see that because of the existing conditions of the horizontal fins, the origami preforms better for solar blocking. The other addition of the origami is the visual identity it brings to the structure. Bringing a better performance and aesthetics to the art of design.

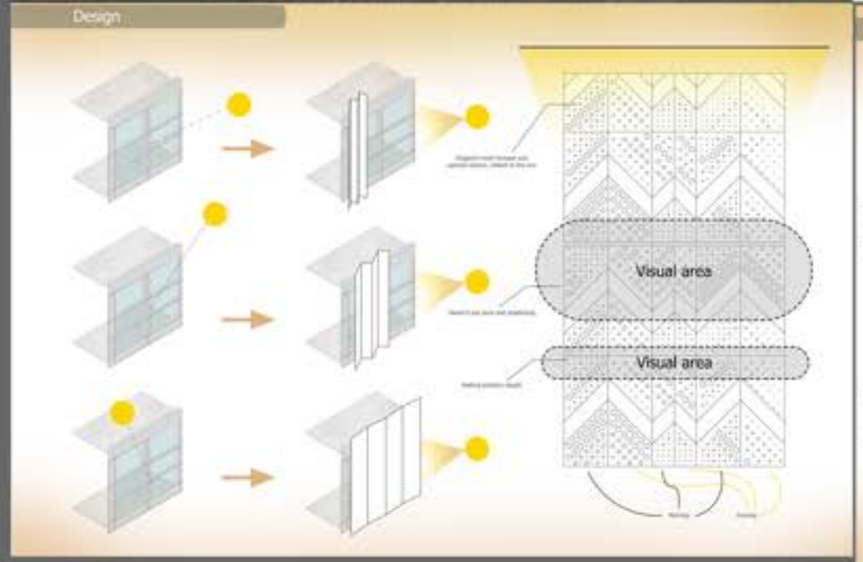
As a final note, I want to fully receive the benefits of this origami facade, so to fully explore this thesis, I have install my 1 to 1 scale model to my bedroom window. The installation is in the interior due to the material of mat board but it does face the south facing side. Similar to the architecture building, I know the conditions of my environment, this can also be said for my bedroom. Where I constantly rely on fans and air conditioning to cool my room down. This origami will most certainly reduce some solar gain to my room.

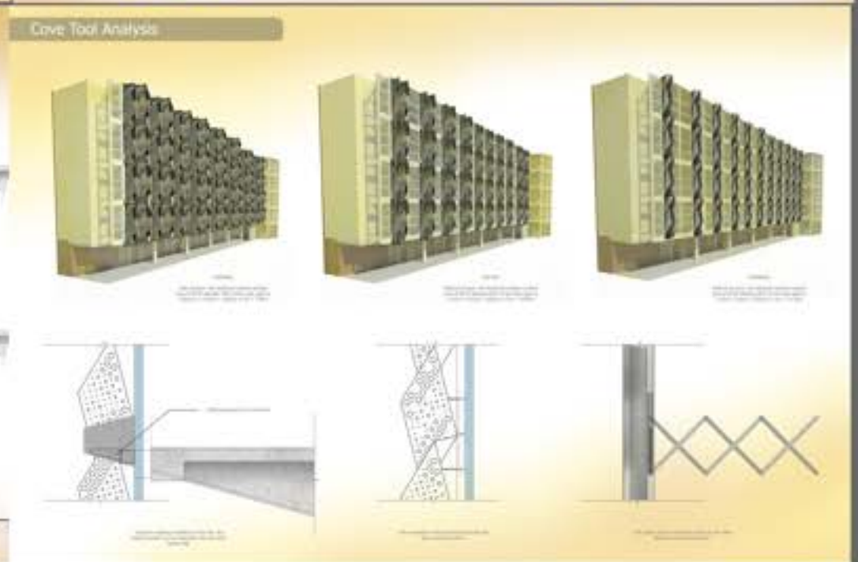


ORIGAMI IN DESIGN

HOW CAN ORIGAMI INFORM THE DESIGN OF THE KINETIC FACADE SYSTEM?







All Image Refrences

1] Image from https://creativemarket.com/
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4] https://www.youtube.com/watch?v=f8N4ozL3PEo
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