Urban Beehive:
A Green Wall System Designed For Bee & Human

Mengyao Liu
May 2021
Syracuse University
School of Architecture
Elizabeth Krietemeyer

ABSTRACT

Bees are a key component and fragile part of our ecosystem and life, with only little known on it. The life cycle of bees provides the necessary steps for pollination of fields and forests. Insect pollination is a critical ecosystem service, espcially for the production of most crops, and therefore essential for food security. "In the USA, the production of pollinator-dependent crops is valued at over $50 billion per year. " [1]

Bees are in danger. Their population is decreasing, and the reason behind is not fully understood. This makes it even more important to learn about and take care of bees. This project aims to address architecture as a container for both human and bees, giving an opportunity to shape an co-living society with nature. Modular beehive prototypes in this project are designed based on biological needs of bees and on facade-integrated opportunities, which challenge pre-conceived notions of what it means to co-live with bees.

CONTENT

01 INTRODUCTION

POSITION STATEMENT

My parents work are related to environment protection that make me have thoughts about it since I was young. During camp experience in middle school, I have been close to nature and observed several insects. These little buzzing neighbours were charming and I wanted to learn about them more.

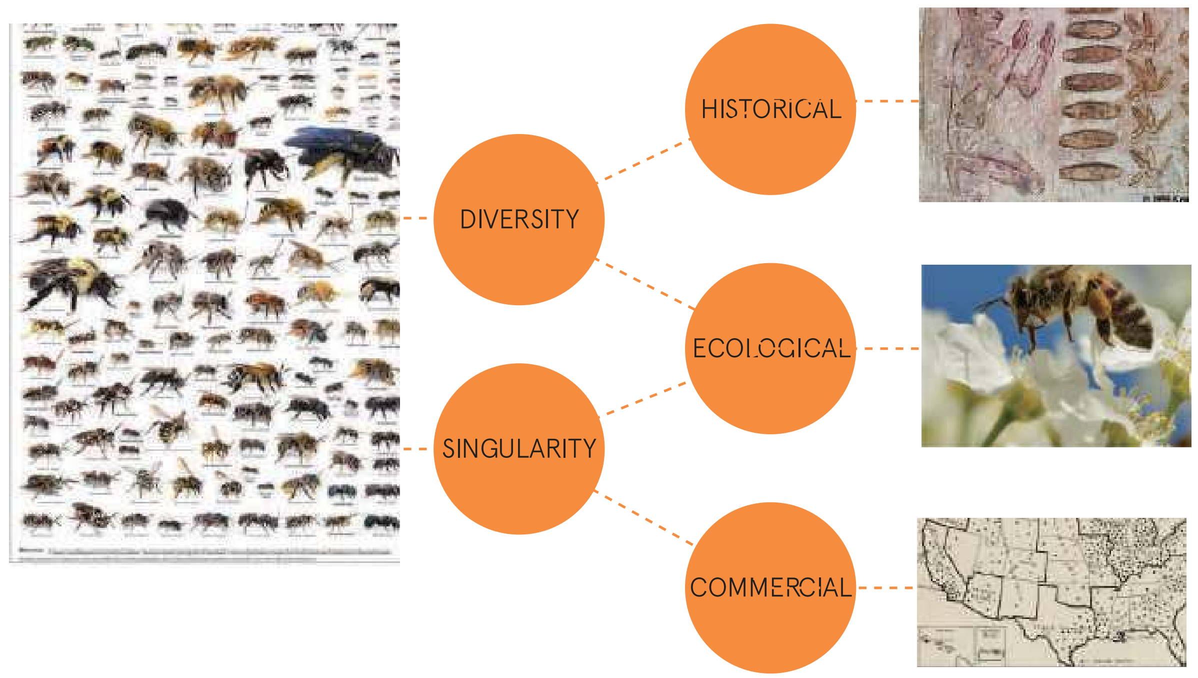
I have worked in several environmental related design during my architecture career, so it is easier to go back and dig deeper in this topic. And I have chance to take an internship in Terreform One, who considers architecture combined with biological field. One of the projects I worked on was called Monarch Sanctuary takes butterfly into their design and inspires me a lot.

SITUATION

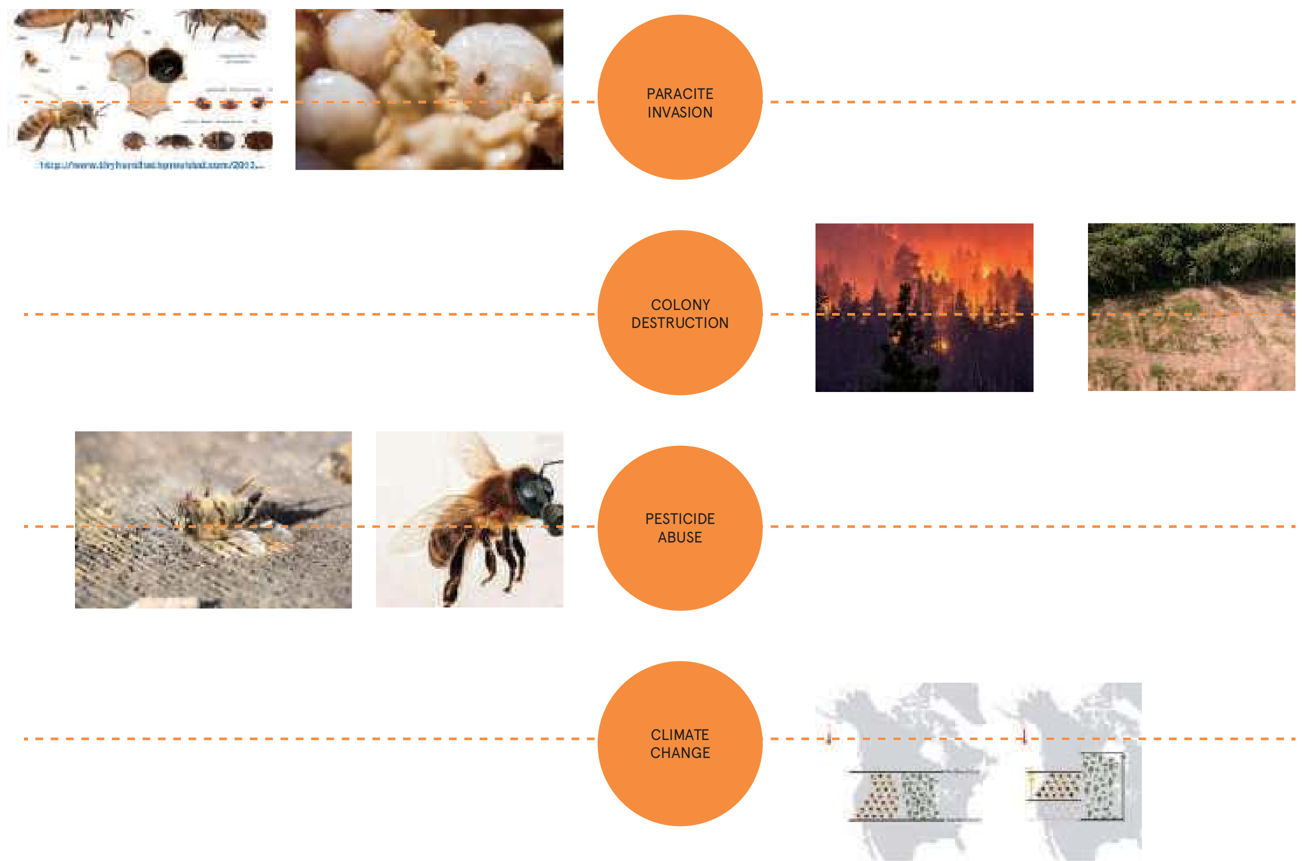
Apis mellifera(European honeybee) is the most commonly kept species, and the only species kept for commercial in America, where is home to 4,400 bee species. Honeybees are the only insect that store food in excess. Their part in high-value commodity production (honey and wax). In America today, the value of honeybees has only increased, as they have become the linchpin in the current agricultural system as pollinators. 30% of the world's most common food crops require honeybee pollination-services.

However, bees are in danger, as their population has declined for decades due to climate change, disease and human activities. Only in US, it is bee community lost 31% than before that by the end of 2012. The same situation also happens in Euroupe and Asia. More worst is that bee colonies shrinks at the same time, both in scale and amount - the population in each native colony decreases from 400k to 45k, which is a warning signal. The majority of bee population is worker bee, collecting pollen, producing nectar, breeding larva and defending invasion. Once a colony has no enough worker, the bee society would cramble and even the queen can barely survive.

(1) Significance of Bee



(2) Risk Factors



QUESTION

CENTRAL QUESTION:
Can we integrete bee habitats into architecture design to preserve the bee population?

SUB QUESTION:
1. What have bio-architects done to create artificial beehives?

2. What are the spacial & atmospheric qualities of beehive?

3. Is there any challenge to apply Urban Beehive to architecture surface?

4. How to be integrated into buildings, and at what scale?

5. What would a facade system integrated with beehive offer to bees and to people?

02 KNOWLEDGE

ARCHITECTURAL EXAMPLES

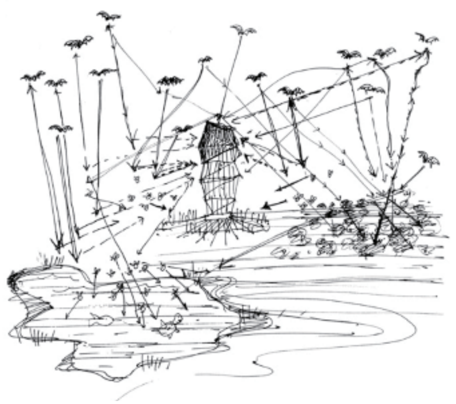
Bat Tower

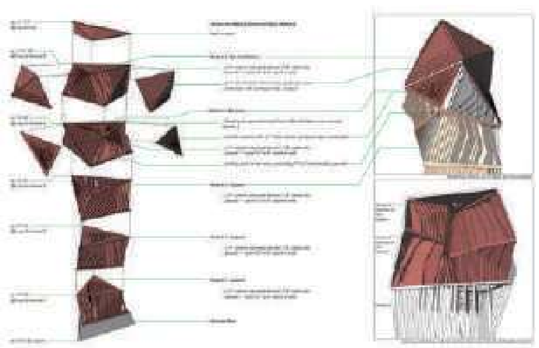
Joyce Hwang 2010 : Griffis Sculpture Park, East Otto, NY : Ashford Hollow Foundation

BAT TOWER is the first built prototype in a series of bat habitation projects which explore strategies for increasing public awareness of bats as a critical component of our ecosystem. Bats are effective as natural pesticides, pollinators, and mosquito abatement. Yet they are often considered as a kind of urban pest, and are frequently exterminated by human-run `pest control' services. Their very survival is also being challenged by White Nose Syndrome, a disease which has inexplicably been wiping out large bat populations in northeastern United States.

In an attempt to bring visibility to bats, BAT TOWER challenges notions of the typical off-the-shelf bat house. Rather than innocuously fading into the background, the tower stands as a prominently visible outdoor sculpture. Drawing from the idea of a vertical cave, the installation has a heavy and intense presence, contrasting the lightness and invisibility associated with do-it-yourself bat house constructions.

BAT TOWER is sited and designed to attract and facilitate bat inhabitation. Located adjacent to a lake, the site boasts an abundance of mosquitoes and other bat-attracting insects. Chives, oregano and other bat-attracting herbs are planted within the base of the tower. To help facilitate entry, the project's ribbed construction includes a series of `landing pads' near the top of the tower. A pattern of grooves on both vertical and horizontal surfaces allows bats to more easily climb into the tower and cling to its `ceilings.' To provide a suitably warm interior for bat roosting, dark wood panels cover the tower's inhabitation zone in order to absorb sunlight.





Bat Tower, Joyce Hwang

The project is an excellent example of one way in which humans can build meaningful and valuable structures that benefit a variety of species. It's also an exciting example of how more modern technologies of rapid prototyping and digital fabrication can be used to create bio-performatic structures (structure behaving with biological systems vs. miming them).

ARCHITECTURAL EXAMPLES

Monarch Sanctuary

TerreformOne, Cooper Hewitt Design Triennial, 2019

The Monarch Sanctuary (Lepidoptera terrarium) will be eight stories of new commercial construction in Nolita, NYC. Programmatically, the building space will mostly contain retail and office life. Yet central to its purpose is serving as a breeding ground and sanctuary for the monarch butterfly (Danaus plexippus). It is a pioneering building – one that aims to be ecologically generous, weaving butterfly conservation strategies into its design through the integration of monarch habitat in its façades, roof, and atrium. Not just a building envelope, the edifice is a new biome of coexistence for people, plants, and butterflies.

This project will vitally serve as a large-scale Lepidoptera terrarium. It will bolster the monarch's presence in the city through two strategies: open plantings of milkweed and nectar flowers on the roof, rear façade, and terrace will provide breeding ground and habitat for wild monarchs, while semi-enclosed colonies in the atrium and street side double-skin façade will foster monarch population growth. The insects will have fluid open access to join the wild population, enhancing overall species population numbers.

The double-skin street façade, with a diagrid structure infilled glass at the outer layer and with "pillows" of EFTE foil at the inner layer, encloses a careful climate - controlled space, 3' deep and 7 stories tall. This "vertical meadow," the terrarium proper, serves as an incubator and safe haven for Monarchs in all seasons. It contains suspended milkweed vines and flowering plants to nourish the butterflies at each stage of their life cycle. Hydrogel bubbles on the EFTE help maintain optimal humidity levels, and sacs of algae help purify the air and the building wastewater. Solar panels on the roof provide renewable energy to assist in the powering the facilities.

Monarch Santuray, Terreform One

BEE HOUSE PRECEDENTS

Vulkan Beehive project

Snøhetta, 2014, Oslo, Norway

The Vulkan Bigard project at Mathallen is a partnership between Aspelin Ramm, Scandic, Sparebankstiftelsen DNB, ByBj Birøkterlag, Heier Du Rietz, and Snøhetta.

The two beehives are appropriately placed at Mathallen, on the rooftop of Dansens Hus, not only for the food and honey relationship, but also naturally and contextually with many of the green spaces in the area, such as Akerselva and Kolonihagen Grünerløkka.

Having two intersecting hexagonal volumes to create the form, which were then adjusted in height and width to fit with the needs of the beekeeper. Using a light colored wood with a finish that is honey in tone was also a relationship that we wanted to create and present.

Vulkan Beehive, Snøhetta

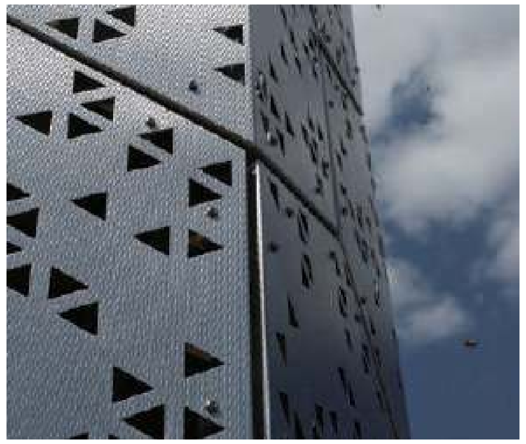
BEE HOUSE PRECEDENTS

Elevator B

University at Buffalo, 2013, Silo City

Elevator B is an urban habitat for a colony of honeybees, which originally occupied a boarded window in an abandoned office building in Buffalo, NY. The site, Silo City, is a group of largely abandoned grain elevators and silos on the Buffalo River. Elevator B is intended as a symbol of the site's environmental and economic regeneration.

This "beecab" provides protection, warmth and separates entry access between bees and humans. Visitors are able to enter the tower, stand below the cypress beecab and look up to view the colony of bees behind glass, similar to an ant farm, as they build their hive. Beekeepers gain access to the hive by lowering it, allowing them to ensure the health and safety of the bees. This feature also caters to the school groups that visit the site, encouraging children to get a close up view.



Elevator B, University at Buffalo

REQUIREMENT FROM HUMAN

(1) Legality

If living in the US, beekeeping is probably legal in most city. However, many cities will have ordinances in place that must be followed, like restrictions on beekeeping such as maximum number of beehives allowed and annual registration in department of argriculture.[11] All those information can be found in several ways:
(1)Local beekeepers association
(2)City's government website
(3)Call local Department of Agriculture
(4)Check State beekeeping law

Bee pollination plays an important role in agriculture contributing to productive crop yields and diverse ecosystems. Bee activity is addressed in two areas of the San Francisco Public Health Code to state that honey bees are not considered a wild or potentially dangerous animal and that honey bees are not considered a public health nuisance just because they're bees.
San Francisco currently allows urban beekeeping without any specific permit requirements; however, in some cases bees can pose significant health and safety risks. To avoid conflict, beekeepers should manage their colonies in a way that's sensitive to surrounding areas and neighbors.

(2) Safety

- Bee Stings
Bee stings produce pain and swelling in the localized area of the sting. This is because the bee releases a stinger that contains venom into the victim's skin. Over time, this pain and swelling is reduced to itching. [12]

- Bee Allergies
Bee stings are bad news for people with bee allergies. In addition to pain and swelling, bee stings result in other symptoms like nausea and vomiting, fainting and closing of the throat in people who are allergic.

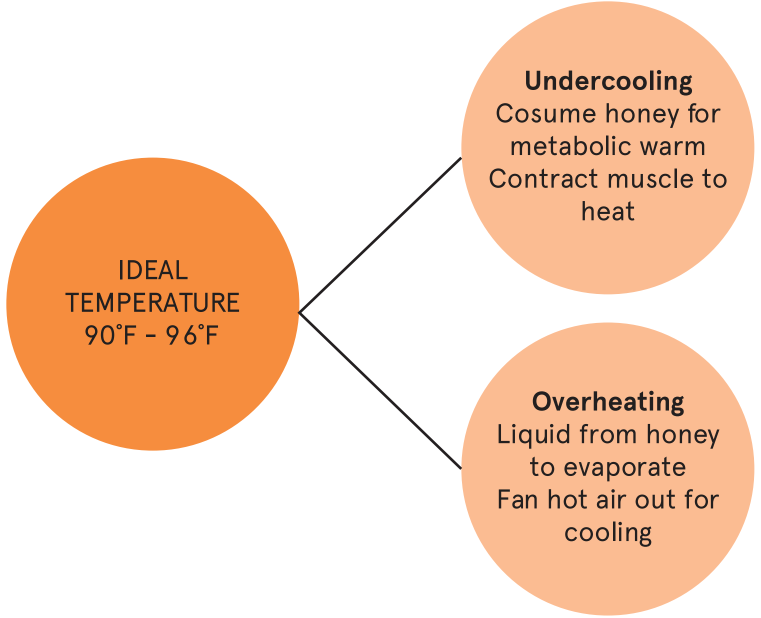
- Bee Aggression
Bees sting as a form of aggression when they feel threatened or if they feel there is a threat to their hive or colony. They also tend to be more aggressive in hot climates, if the hive is located in a shady area or if there is a lack of flowering plants.

CREITERIAL FOR BEE

(3)Temperature

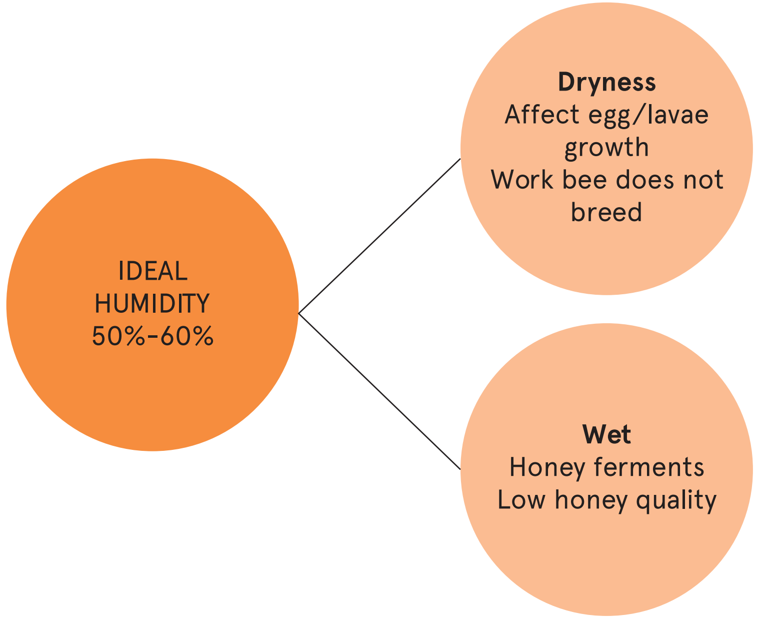
Brood nest temperature is of extreme importance to the colony and is controlled with utmost precision. Honey bees maintain the temperature of the brood nest between 32°C (90°F)and optimally 35°C(96°F) so that the brood develops normally.

When the temperature in the nest is too high, the bees ventilate by fanning the hot air out of the nest or use evaporative cooling mechanisms.
When the temperature is too low bees generate metabolic heat by contracting and relaxing their flight muscles (having uncoupled the wings from them). The resulting vibration generates heat in those muscles. (Winston 1987, Tautz, 2008) [5]



(4)Humidity

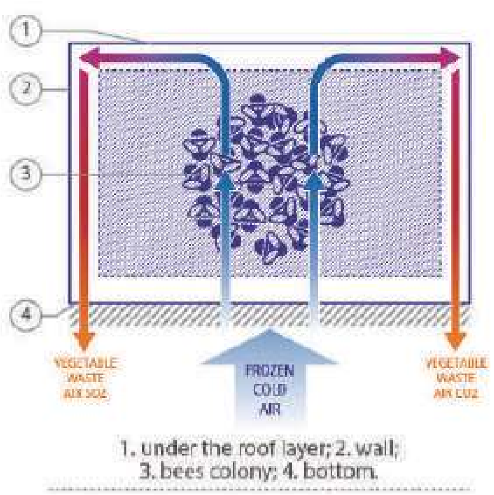
Honey is hygroscopic, which means it will absorb moisture from a high humidity environment.Having a high moisture content in honey lowers quality and leads to fermentation.
It's also hydrophilic, which means it will release moisture when there is low humidity. [5]



CREITERIAL FOR BEE

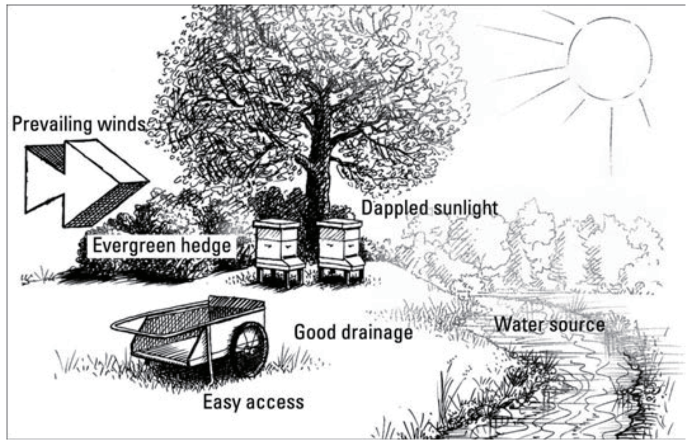
(5)Ventilation

The vebtilation box is used to give any moisture that builds up a way to escape.
Filled with fiberglass insulation, it also works to prevent condensation from developing on the underside of the outer cover.
If this cold condensation is allowed to form, it drips down on the bee cluster chilling them to the point that they may not survive.[7]



(6)Shading

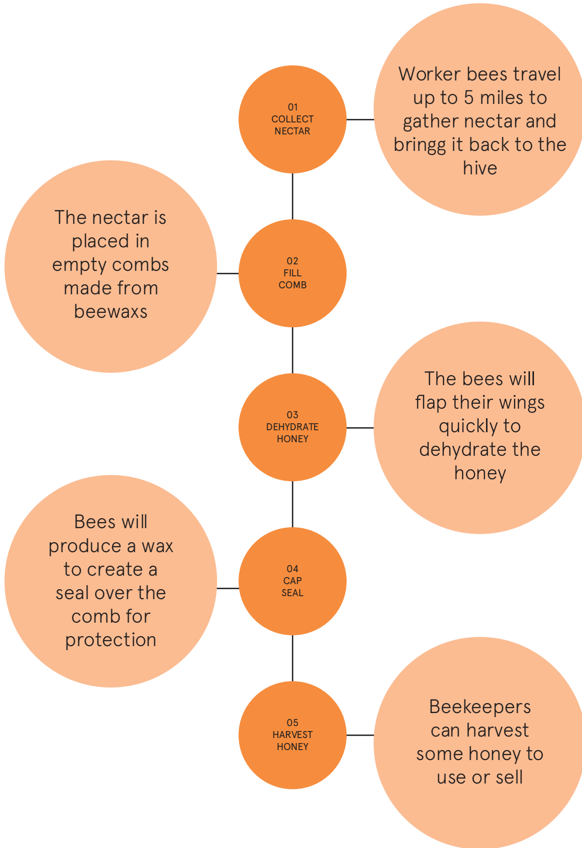
Put the hive in dappled sunlight.
Full, direct sun all day long causes the hives to get very hot in the summer. The bees will spend valuable time trying to regulate the hive's temperature (rather than making honey).
You also want to avoid deep, dark shade because it can make the hive damp and the colony listless.[8]



CRITERIA FOR BEE

(7) Honey Producing

Bees need two different kinds of food. One is honey made from nectar, the sugary juice that collects in the heart of the flowers. The other comes from the anthers of flowers, which contain numerous small grains called pollen. Just as flowers have different colours, so do their pollen.



Step 1: Worker bees collect nectar.
When the worker bee has found a good source of nectar, she gets to work! Using her proboscis, she sucks up nectar from the inside of flowers, often visiting more than 100 flowers on one foraging trip.

Step 2: Worker bees pass the nectar to house bees.
Back at the hive, bees known as house bees wait for the foragers to return. The worker bees pass the nectar to the waiting bees so they can really start the honey-making process. As the nectar is chewed and passed from bee to bee, enzymes change its Ph and other chemical properties, as well as reducing moisture in honey.

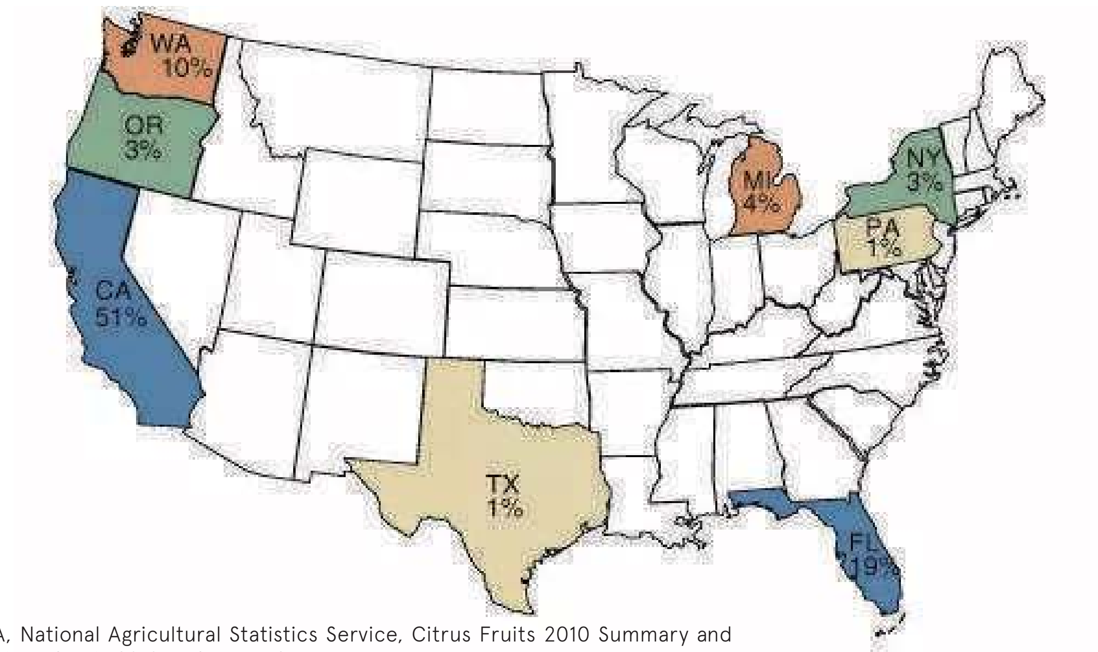
Step 3: The bees dehydrate the honey.
Some water is removed from the honey while it is passed from bee to bee. Bees use two other methods for further drying out the honey. For one, they will spread the honey over the honeycomb to allows for more water evaporation. The other is fanning with wings near the honey to accelarate airflow. Eventually, the honey will have a water content of about 17-20%, down from a whopping 70%.

Step 4: The bees cap the honeycomb with beeswax.
The final step in the honey-making process is storage. The honey is deposited into the cells of the honeycomb, where it will stay until the bees are ready to eat it. To keep the honey fresh, each cell is capped with beeswax.[10]

SITE SITUATION

California [9]
- 2019 top agricultural exports:
- #1. Tree nuts: $8.5 billion (#1 among all states)
- #2. Other plant products: $3.4 billion (#1)
- #3. Fruits, fresh: $2.8 billion (#1)
- #6. Vegetables, fresh: $1.2 billion (#1)

Average temperatures across the state are in a temperate zone of 50°F (10°C) to 80°F (26.7°C) with many sunny days during the month and the relatively meager amount of rain. Humidity is 65%, with mostly clear skies and mild nights.



Source: USDA, National Agricultural Statistics Service, Citrus Fruits 2010 Summary and Noncitrus Fruits and Nuts 2010 Preliminary Summary.

The latest results, which cover up to April 1 2019, show a slight decrease in the honeybee population, both in California and nationwide. In California, there were 30,000 fewer honeybee colonies between Jan. 1, 2017 and Jan. 1, 2019, a loss of about 2.6 percent of the state's honeybee colony population.

Previous surveys showed a loss of 19 percent of honeybee colonies in California between 2015 and 2017, about 270,000 colonies lost. Nationwide, the decrease was smaller, with honeybee colonies during that time decreasing from about 2.8 million to 2.6 million.

California particularly needs honeybees for pollinating crops such as almonds, apples, avocados and grapes.

Honeybees have had to be shipped into California to help with almond pollination particularly. Gordon Frankie, who researches bees for the Univeristy of California at Berkeley Essig Museum of Entomology, said the loss of the survey is "horrible."

BEE POPULATION DECLINED

BEE COLONY SHRANK

KEY CROP POLLINATION

BEE SHIPPING

03 METHODOLOGY

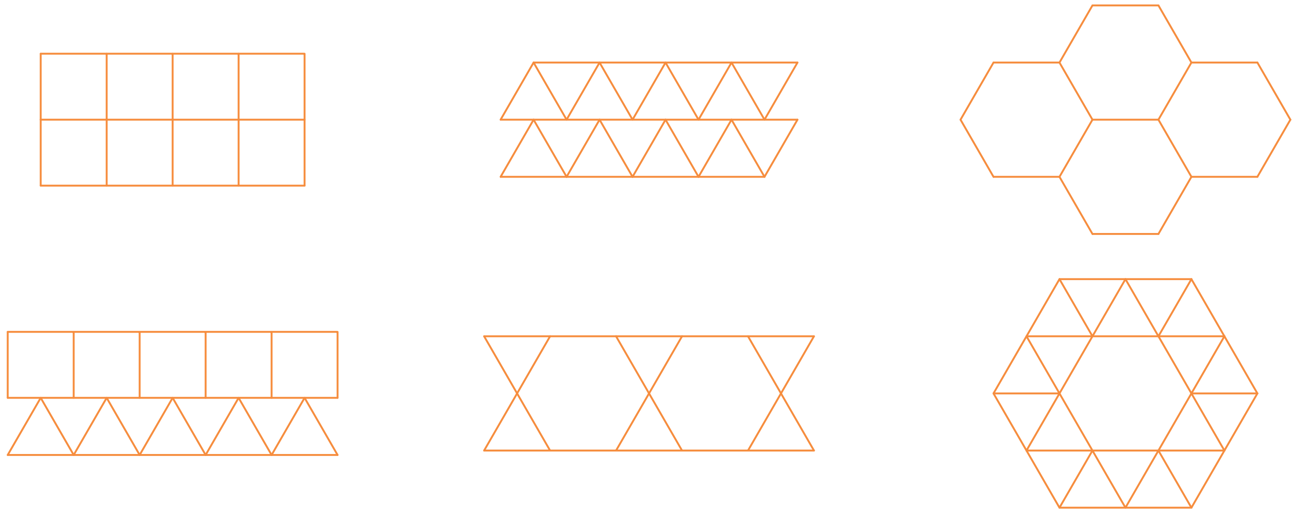
SYSTEM DESIGN

1. Tiling/Tessellation
A periodic tiling has a repeating pattern.

Some special kinds include regular tilings with regular polygonal tiles all of the same shape, and semiregular tilings with regular tiles of more than one shape and with every corner identically arranged.

The patterns formed by periodic tilings can be categorized into 17 wallpaper groups. A tiling that lacks a repeating pattern is called "non-periodic". An aperiodic tiling uses a small set of tile shapes that cannot form a repeating pattern.

In the geometry of higher dimensions, a space-filling or honeycomb is also called a tessellation of space.



(1) Symmetry: Only square, triangle and hexagon can do tiling without any slant, ensuring they can keep honeycomb perpendicular no matter which direction they are.

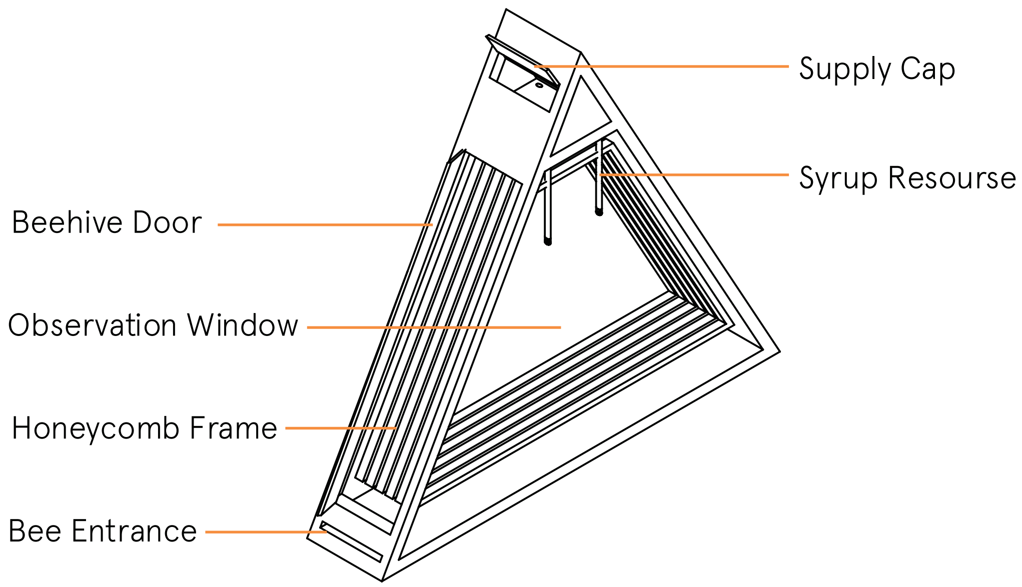
(2) Fexibility: Among these three geometries, when applied with same perimeter, the area for each declines from hexagon(0.07216) to square(0.0625) to triangle(0.04811). The smallest area of triangle can adapt to various surface and form. For honeycomb built inside, wide and shallow are benefit to stregthen its stability as deep narrow ones would crack easily.

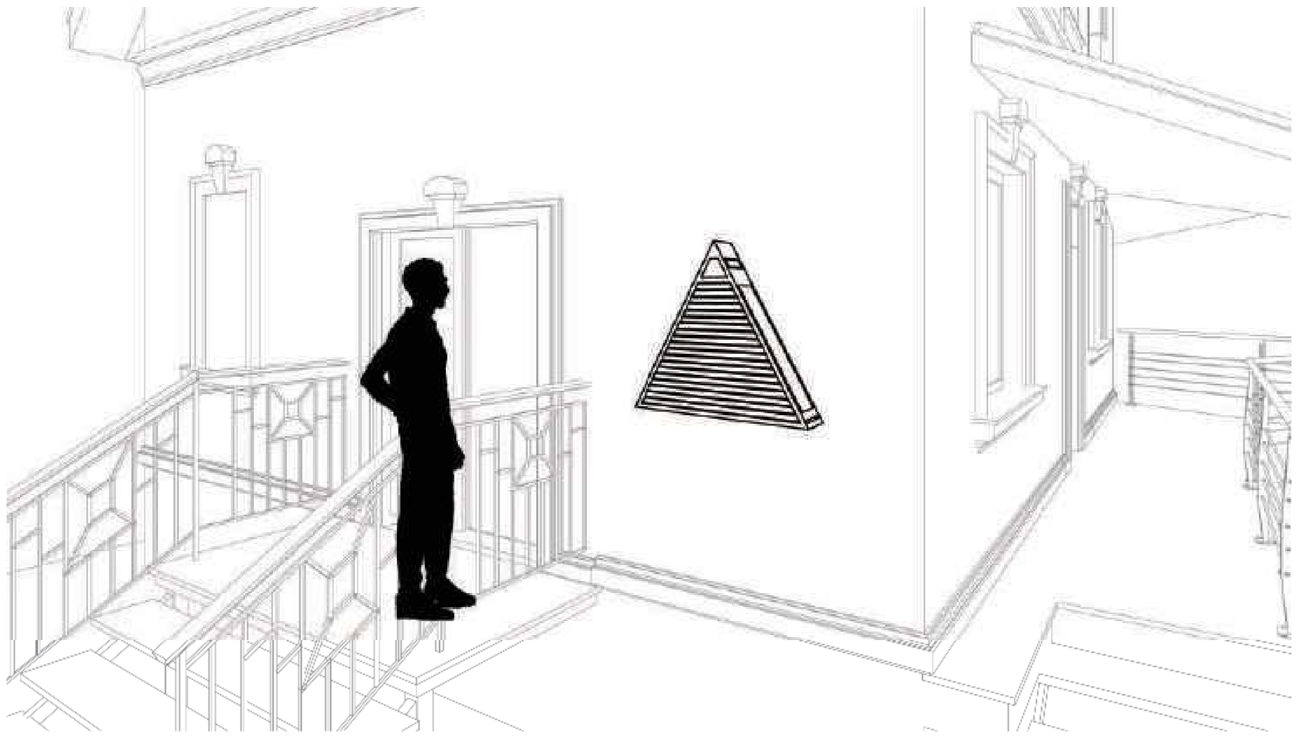
(3) Adhesiveness: The honeycomb grows vertical first and later on expands to lateral. However, the honeycomb would spread out of its frame if are not moved frequently by beekeepers and stick to beehive box tightly, and need be trimmed before any movement, causing damage part of the comb - the slant of box can help reduce this problem.

(4) Management: Bees build honeycomb along any surface and fill in all the space once they got enough worker bee and food source.

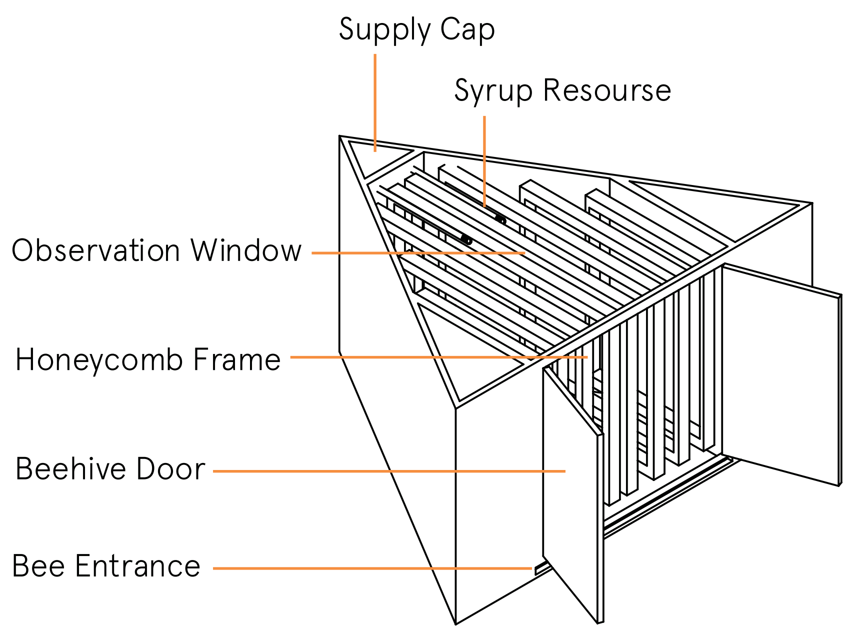
The honeycomb construction process

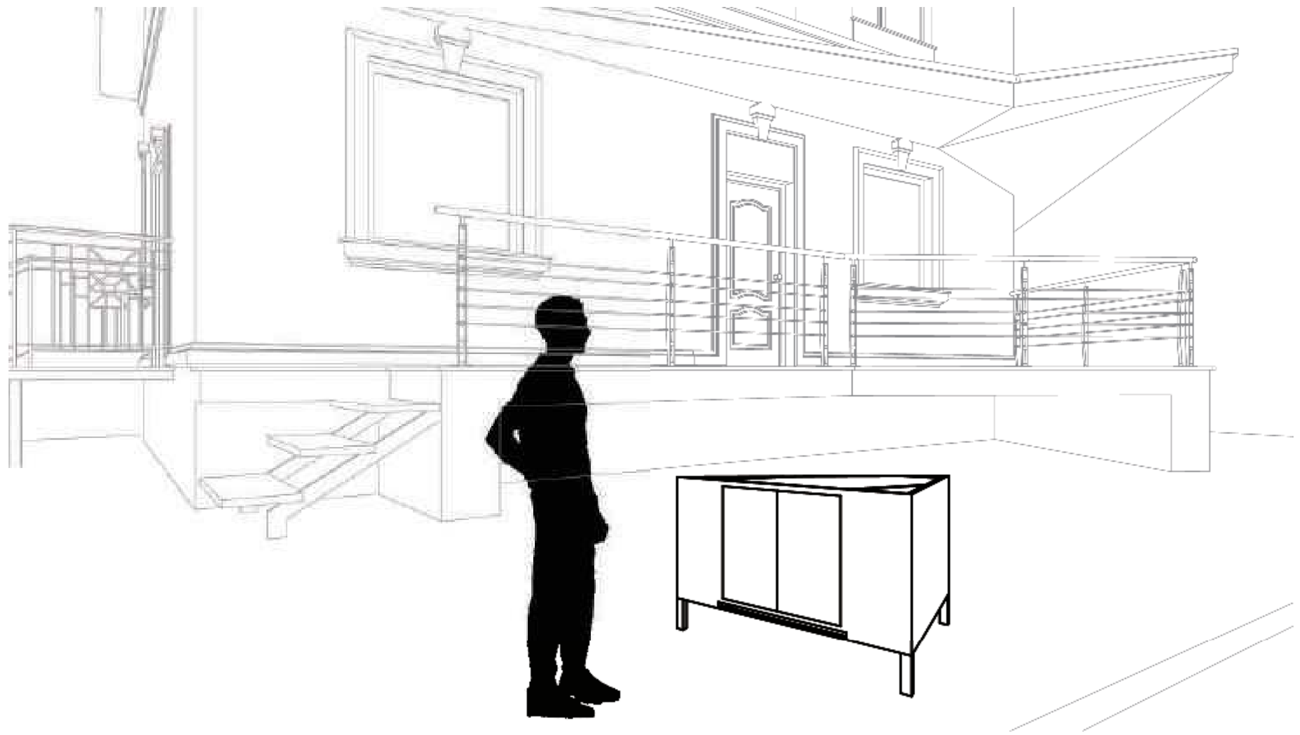
SYSTEM DESIGN
2. Prototype
(1) Vertiacal Surface



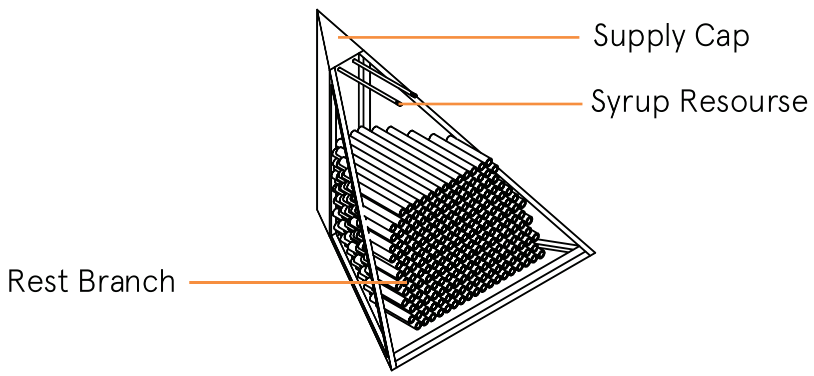


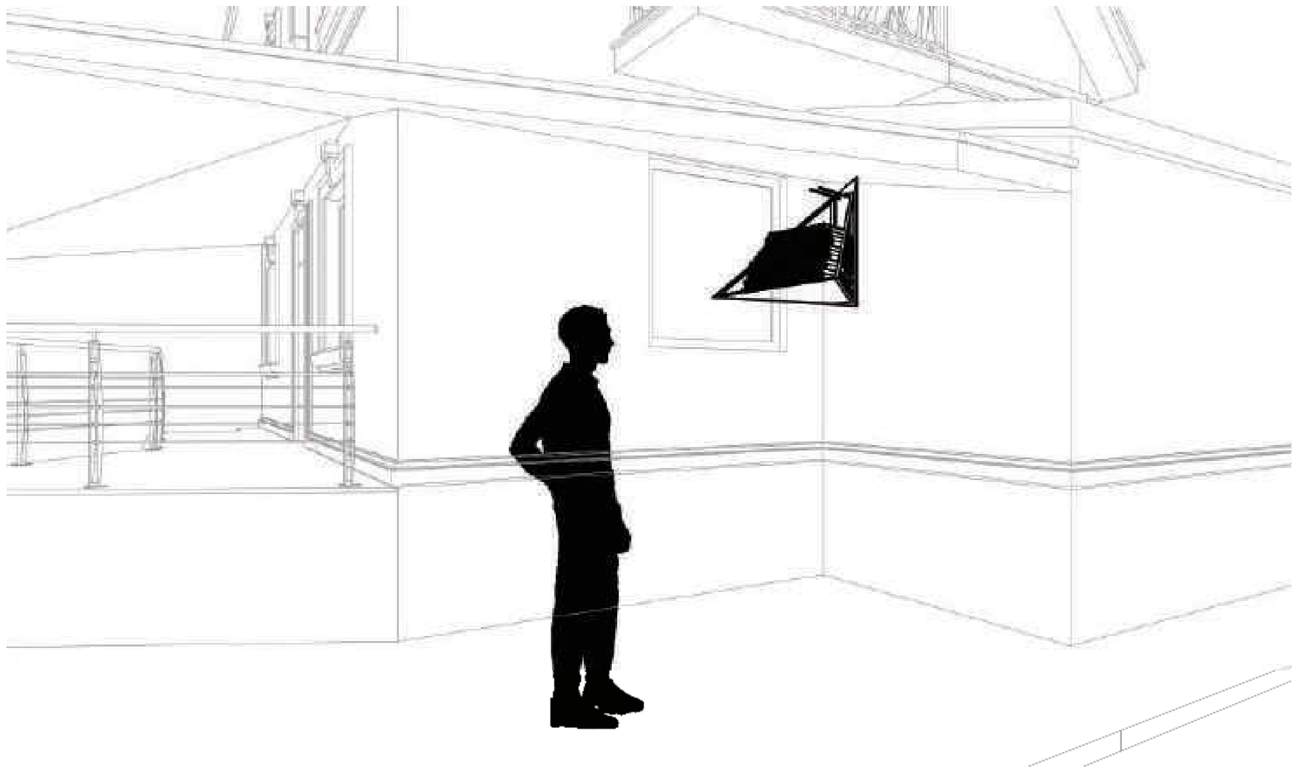
SYSTEM DESIGN
(2) Horizontal Surface



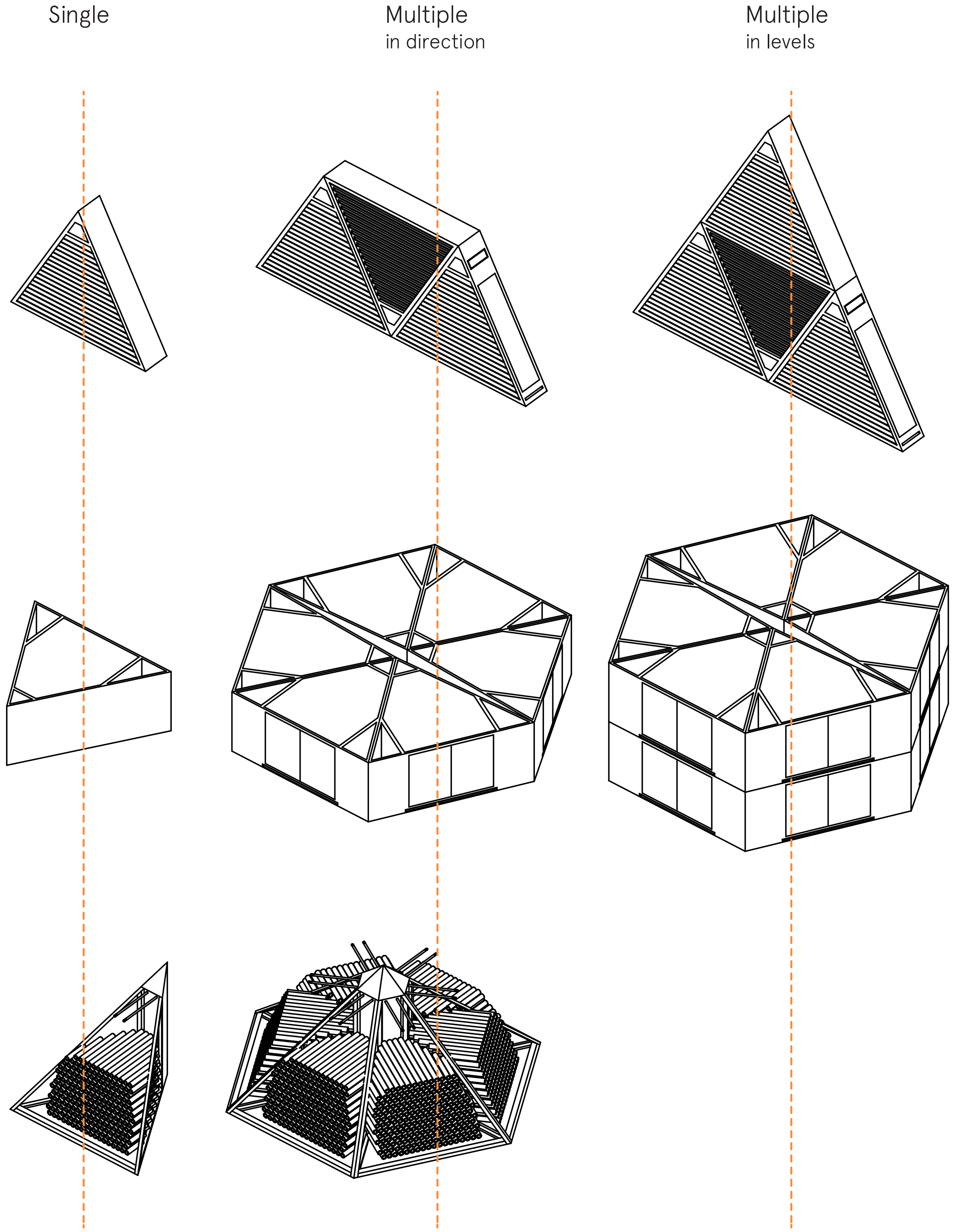


SYSTEM DESIGN
(3) Hanging Station





PROTOTYPE TEST
(1) Multiplication

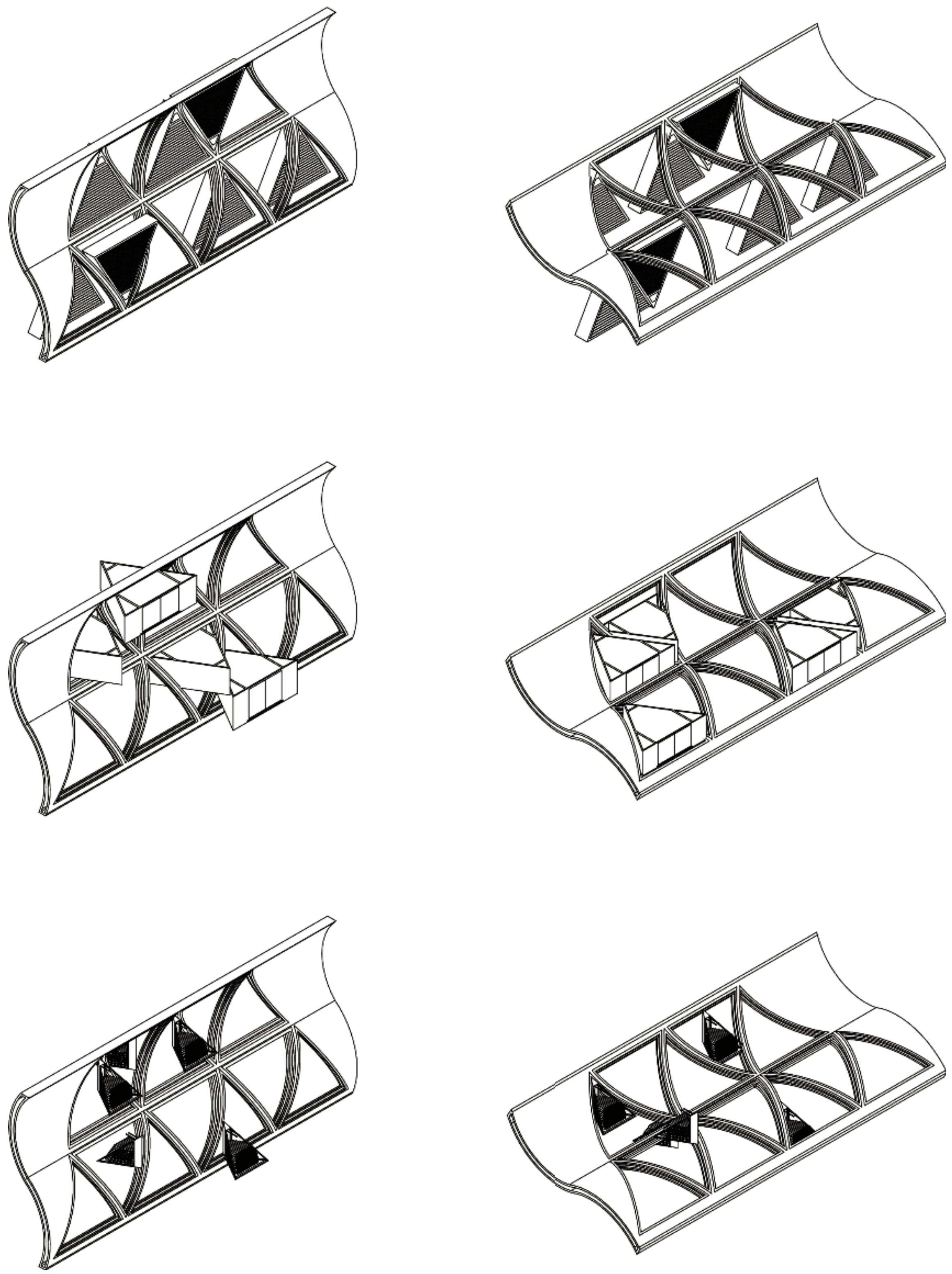


PROTOTYPE TEST

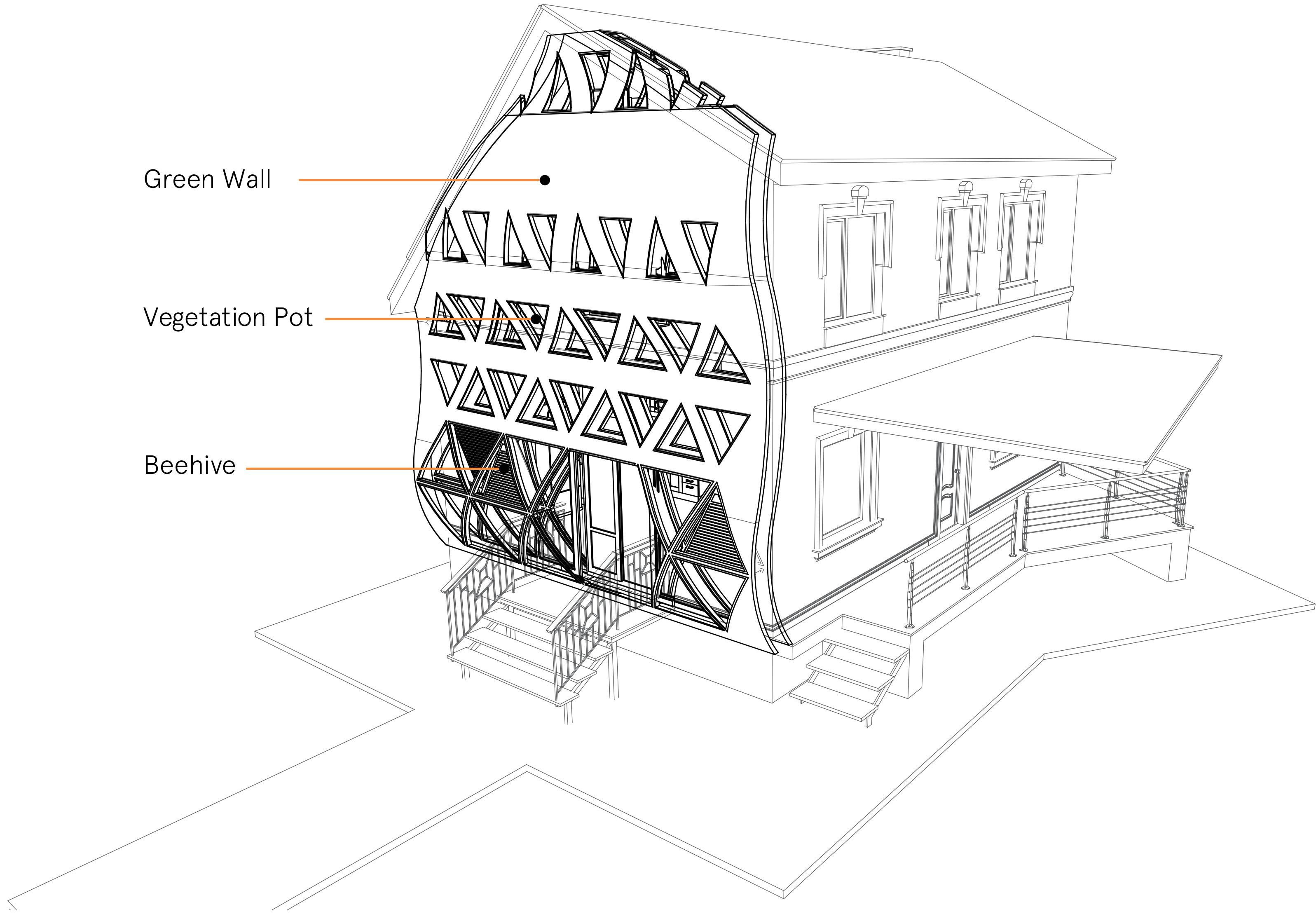
(2) Flexibility

Vertical Position

Horizontal Position



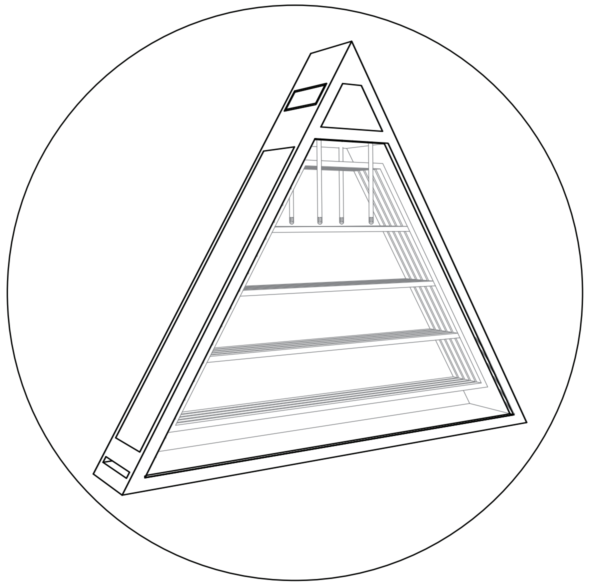
APPLICATION - GREEN WALL



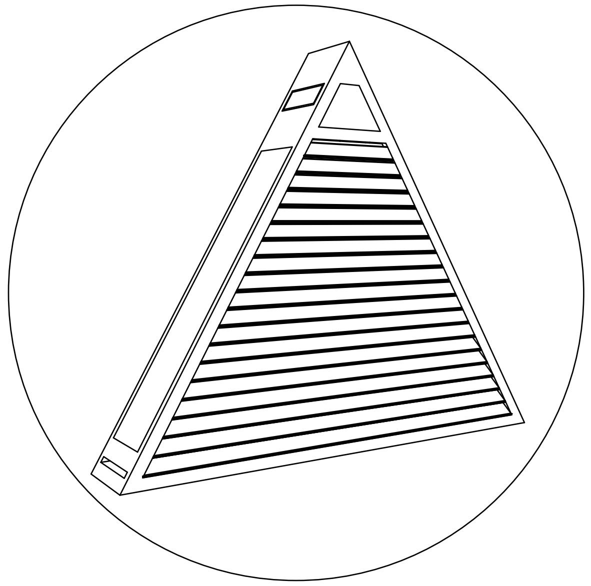
04 OUTCOME

DETAIL DRAWING

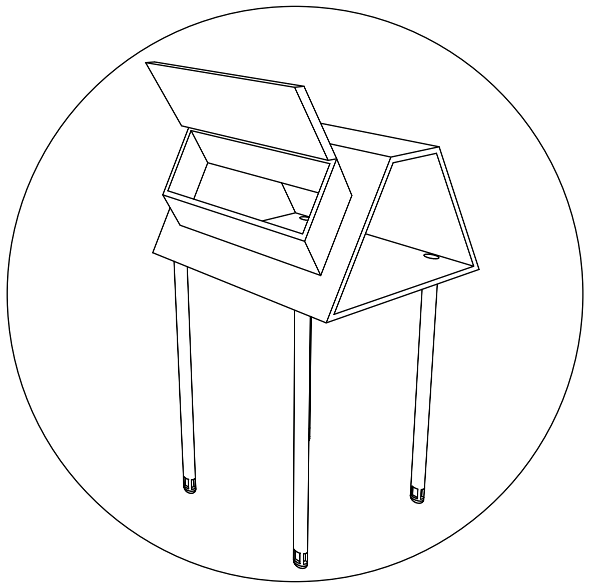
(1) Beehive Facility



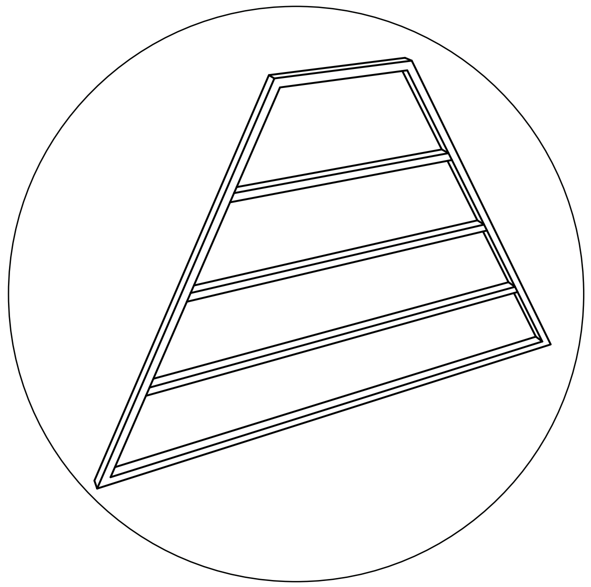
Observation Window



Operable Louver



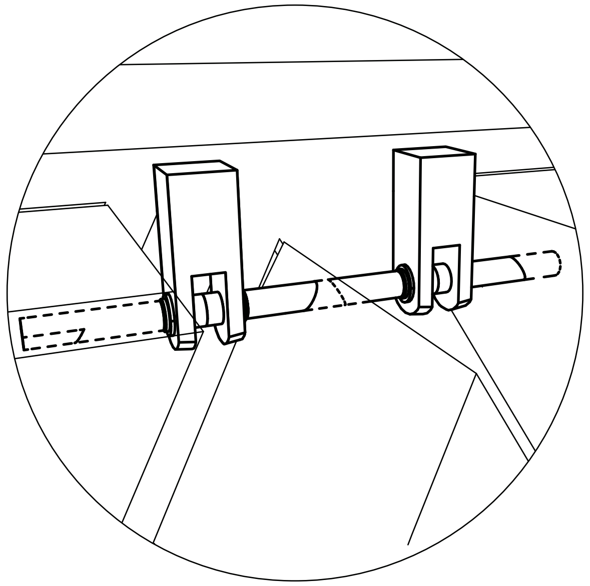
Syrup Supply



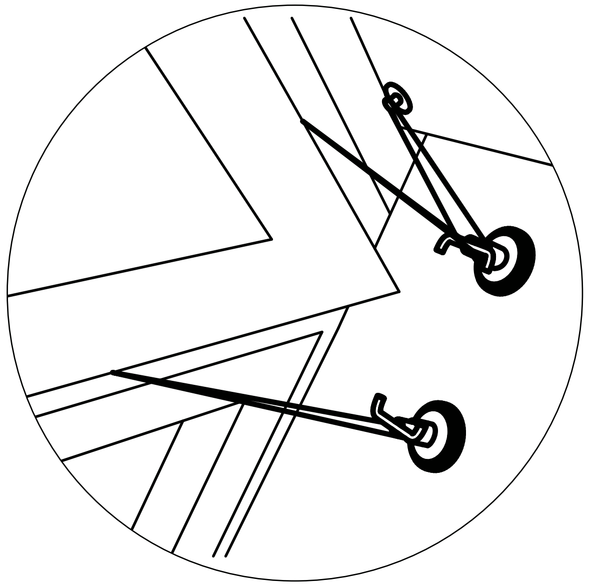
Honeycomb Frame

DETAIL DRAWING

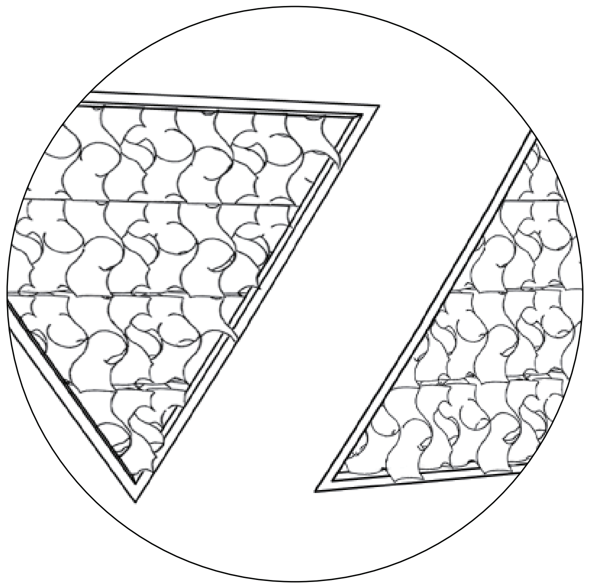
(2) Green Wall



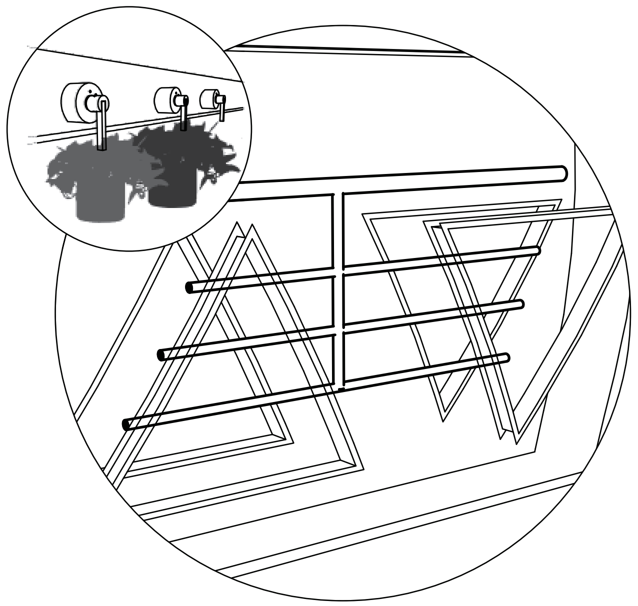
Fixing Joint A



Fixing Joint B



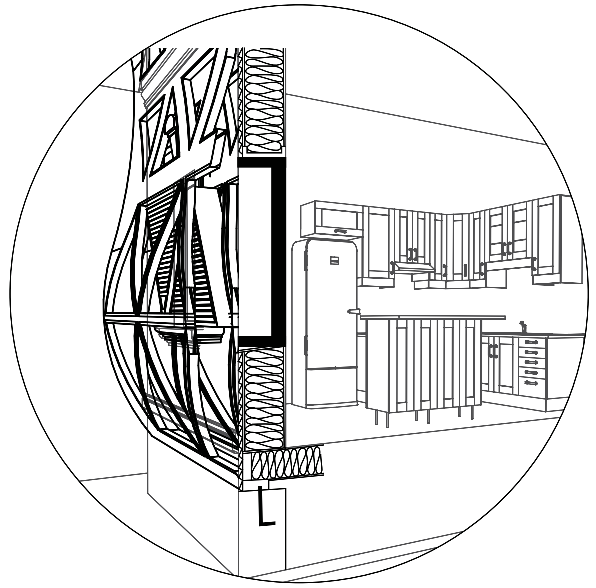
Vegetation Pot



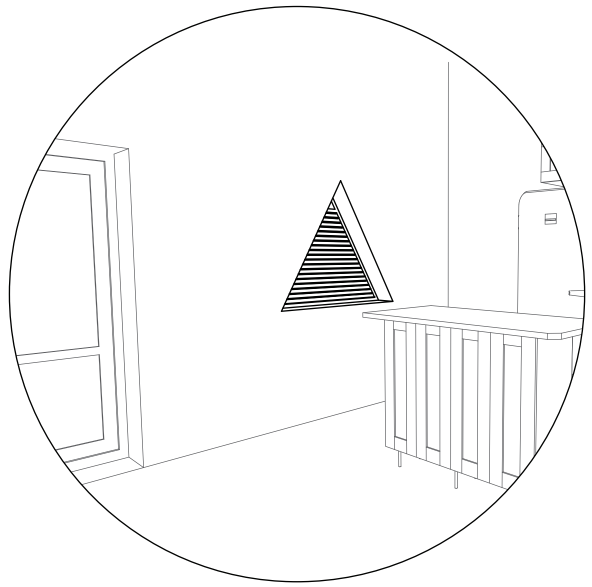
Irrigation System

DETAIL DRAWING

(3) Attaching to Wall

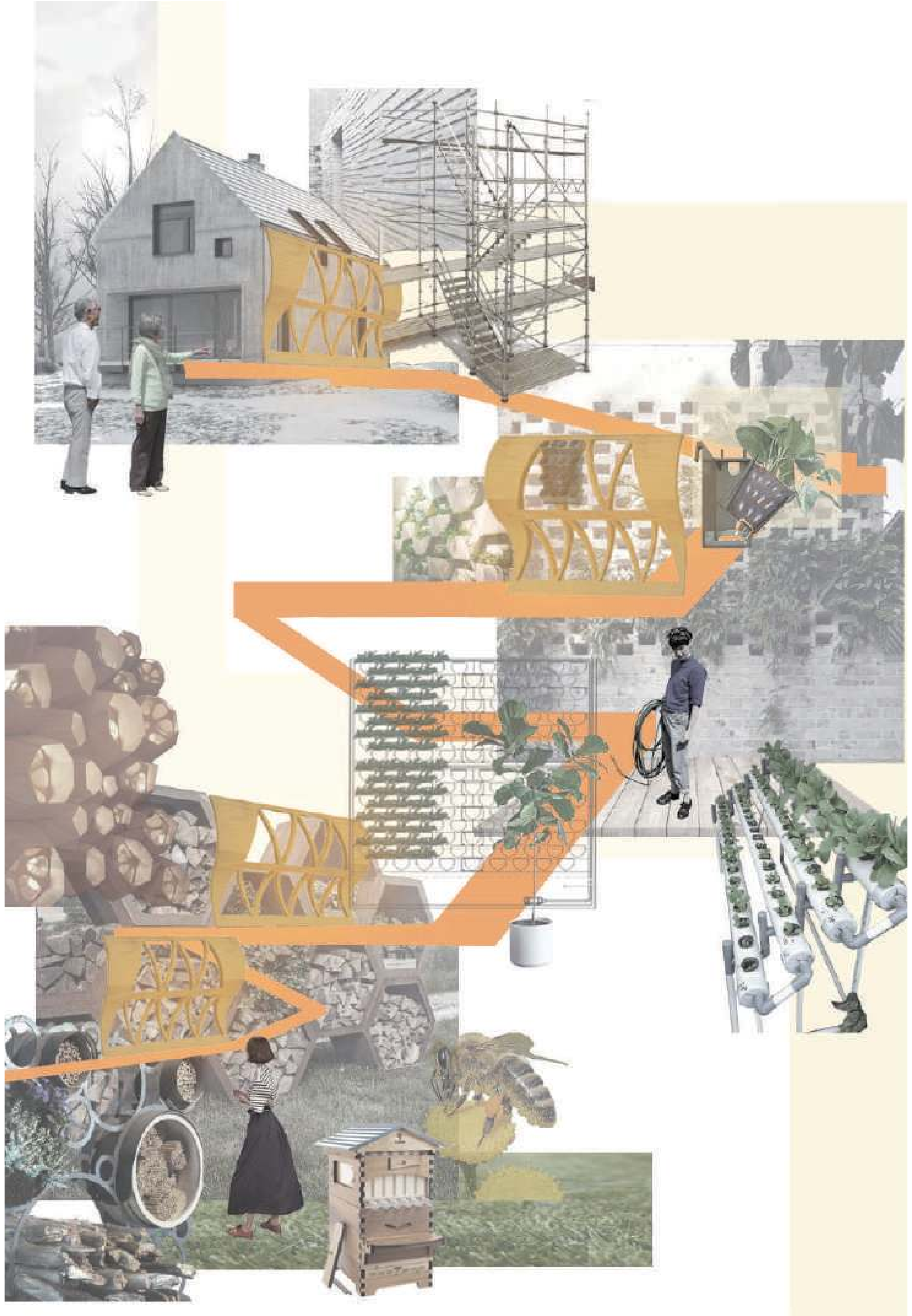


Bee Barrier

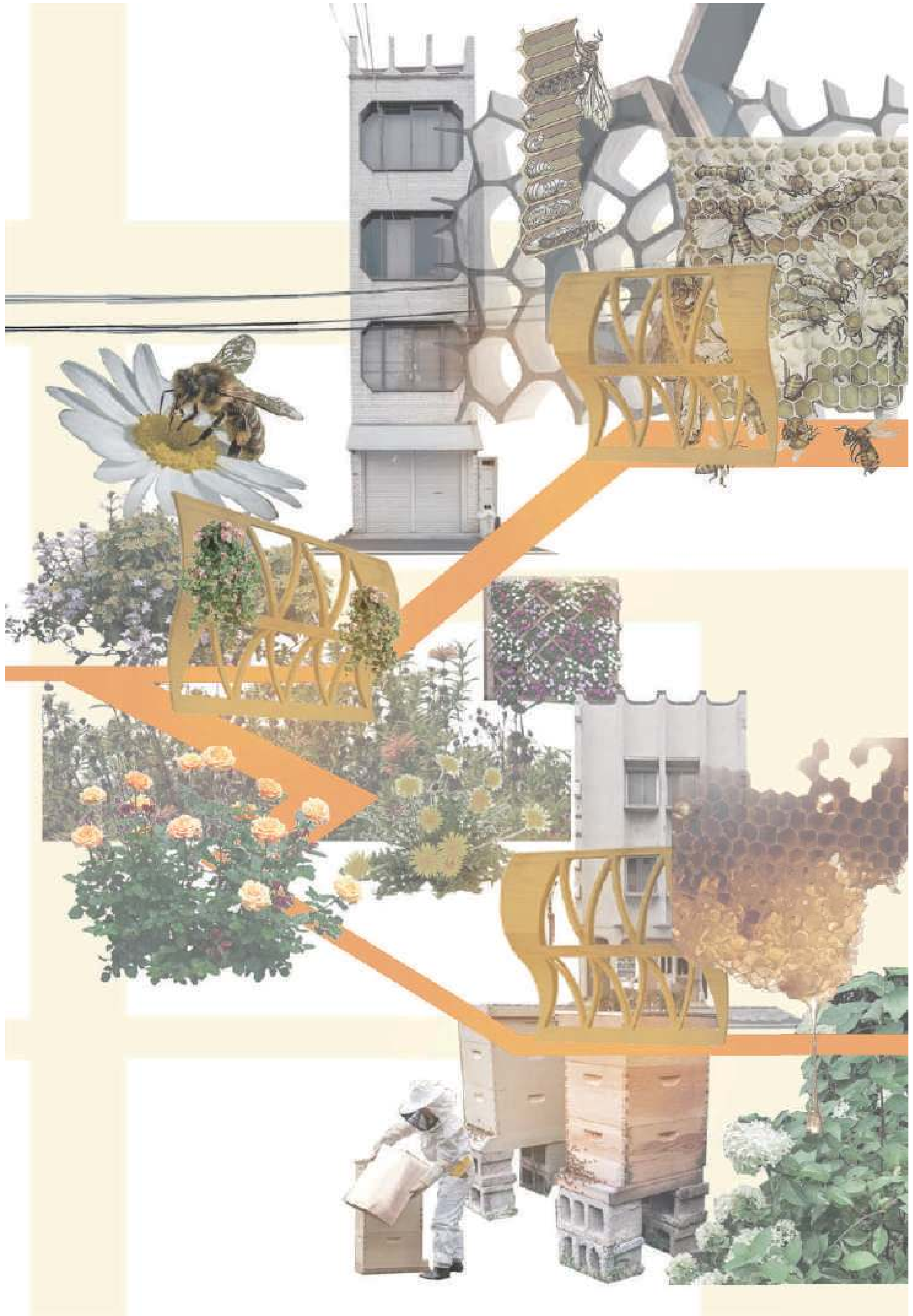


Observation Window

INTRODUCE BEE INTO YOUR HOUSE



LIFE IN A BEEHIVE



MEDIOGRAPHY

7
Bat Tower
2010 : Griffis Sculpture Park, East Otto, NY : Ashford Hollow Foundation
Hwang, Joyce. "Ants Of The Prairie. Bat Tower"
http://www.antsoftheprairie.com/?page_id=203
Photograph: Albert Chao, Nellie Niespodzinski, Angela Wu

8
Monarch Sanctuary
Terreform One, Cooper Hewitt Design Triennial, 2019
Terreform One, "Monarch Sancturay", Projects, Intelm BASF
https://terreform.org/monarch-sanctuary

9
Vulkan Beehive
Snohetta, "Vulkan Beehive ", Projects, Aspelin Ramm, Scandic, Sparebankstiftelsen DNB, ByBj Birøkterlag, Heier Du Rietz
2014, https://snohetta.com/projects/186-vulkan-beehive

10
Elevator B
Amy Frearson, "Skyscraper for bees by University at Buffalo students", dezeen, last modified by 6 May, 2013, https://www.dezeen.com/2013/05/06/skyscraper-for-bees-by-university-at-buffalo-students/
Courtney Creenan, Kyle Mastalinski, Daniel Nead, Scott Selin, Lisa Stern, "Elevator B", News&Events, Rigidized Metals Corporation
2012, http://ap.buffalo.edu/news-events.host.html/content/shared/ap/articles/work/2013/elevator-b.detail.html

11
Legality
Holly, "Is beekeeping legal in my city?",Complete Beehives, last modified by 6 Aug, 2019. https://completebeehives.com/is-beekeeping-legal-in-my-city/

Safety
Ram, R., Swarnalatha, G., Ashok, K.K., anconi syndrome following honeybee stings. Switzerland: Int Urol Nephrol, 2012. Springer.

12
Image on the top
Backyard Bees of North America - Joseph S. Wilson & Olivia Carril
Beekeeping shown in the toms of Pabasa - Manchester Museum
Honeybee on a bird cherry - Ivar Leidus
Economic aspects of the bee industry - The Bookworm Collection / Alamy Stock Photo

Image on the bottom
Varroa Mite - Psalm, "The Hand Hath Provide - Living Simply In Order To Give", last modified by 13 May, 2013. http://www.thyhandhathprovided.com/2013/05/hive-inspection-1.html
- Countryside Magazin Contributor, "The Varroa Mite: Know Your Enemy", posted on 17 January, 2021. https://backyardbeekeeping.iamcountryside.com/health-pests/the-varroa-mite/
Wild Fire - Stuart Palley
Deforestation - Joao Laet, AFP
Pesticidcd Abuse - twitter@Philippebramedi
- Jared Belson
Climate Change - Kerr er al, Science 2015

13
Tautz, J. *The Buzz about Bees*. Berlin: Springer-Verlag, 2008.

14
Ventilation
Beehive Super - Windy Meadows Farm, "Welcom to our 1864 farmhouse...life is good!", posted on 14 Novemver, 2012. https://windymeadowsfarm.blogspot.com/2012/11/building-hive-ventilation-box.html
Ventilation Sectional Diagram - Beehouse, "Ventilation in beehives made of polyurethane foam", posted on 15 April, 2019. https://beehouse.global/en/ventilyatsiya-v-ulyakh-iz-penopoliuretana/

Shading
Blackiston, Howland, "Pick the Perfect Location for Your Beehive", Dummies. https://www.dummies.com/home-garden/hobby-farming/beekeeping/pick-the-perfect-location-for-your-beehive/

15
Detk Live Bee Removal, "How Do Bees Make Honney?", DTEK, posted on 16 Oct, 2019. https://dteklivebeeremoval.com/how-do-bees-make-honey/

16
Andrew, Lisa, "Biggest agricultural exports in every state", Stacker, posted on 28 Jan, 2021. https://stacker.com/stories/3731/biggest-agricultural-exports-every-state
Map - USDA, National Agricultural Statistics Service, Citrus Fruits 2010 Summary and Noncitrus Fruits and Nuts 2010 Preliminary Summary.

18
Pickover, Clifford A. (2009). The Math Book: From Pythagoras to the 57th Dimension, 250 Milestones in the History of Mathematics. Sterling. p. 372. ISBN 9781402757969.

19
HoneyComb Process - Courtesy Technical World, https://en.wikisource.org/wiki/Page:LA2-NSRW-1-0238.jpg
Bees in a natural hive - Bilby, posted on 11 September, 2010