SCAD

Biomimicry Methodology | Professor Scott Boylston

OASYS

OMNI-AGRICULTURAL SYSTEM

Process Book

Adero Brooks | Celine Diz | Em Cote | Erin Hull | Samiha Khan

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Small but mighty, Morph is a diverse team of five SCAD students coming from various backgrounds of design: Industrial Design, Architecture, Interior Design, User Experience, Sustainable Design, Design Management, and even Textile Design. We have come together to apply our unique methods of design and exploration to understand biomimicry methodology. Along this journey, you will find how we as a team tackle and experience the various phases of designing from biology to design. This began with quieting our human cleverness and observing the natural environment through an unfiltered lense, leading all the way to extensive research, problem-solving, and conceptualization to solve a real world problem. With the Biomimetic process, Team Morph has slowly but surely developed a design honoring the cleverness of the world around us rather than ourselves.

Understanding Biomimicry

From behavior to biological makeup, humans are intrinsically linked to all systems and life on Earth. Biomimicry is a tool to help humans reconnect to our oneness and begin to understand nature as our mentor; understanding that we have the incredible opportunity to learn from the natural world to enhance our human experience. It encourages us to quiet human cleverness and understand that we *are* nature; and that there is no separation. With this, we are able to seek how natural forms, processes, and ecosystems in place can be mimicked to minimize our negative impact on Earth. Nature has already solved problems that we are still trying to manage; including climate control, efficient transportation and energy production, and much more. Learning from and emulating our findings to create more sustainable designs allows us to

"work as a system and create conditions conducive to life."
(biomimicry 3.8)

PHASE I

An Array of Species

“Falling in love” with our species

Screenshot of species research from our miro board showing our color coded function cards and colored hearts for voting.

We began our process on asknature.com exploring 25 different species and identifying unique functions of each. We compiled function cards-each containing a species image, its name, description, strategy, function, mechanism, a design principle and potential applications in the design industries. This process helped us seek inspiration for design by exploring a whole new realm of possibilities via existing life-friendly models. We organized the species we “fell in love” with their function cards.

Each row of functions cards was color coded in order to differentiate between the species each one of us researched. We then went through a selection process by voting based on which species we felt were most interesting and with the most potential for design based on the studied species'

mechanism, strategy and functions. This process brought us to the following 5 species; the *Begonia pavonina,* the tortoise turtle, the *Lecanora conizaeoides lichen*, the Sacred lotus, and the Earwig. Our next step was brainstorming contextual potential applications for each of the chosen species. Function cards for each species are shown below.

Function Cards & Design functions →

Name

Earwig

Genus

Forficula Auricularia

Strategy

Intricately strategic joints allow earwig wings to spread out without muscle use

Function

Optimize Shape & Materials

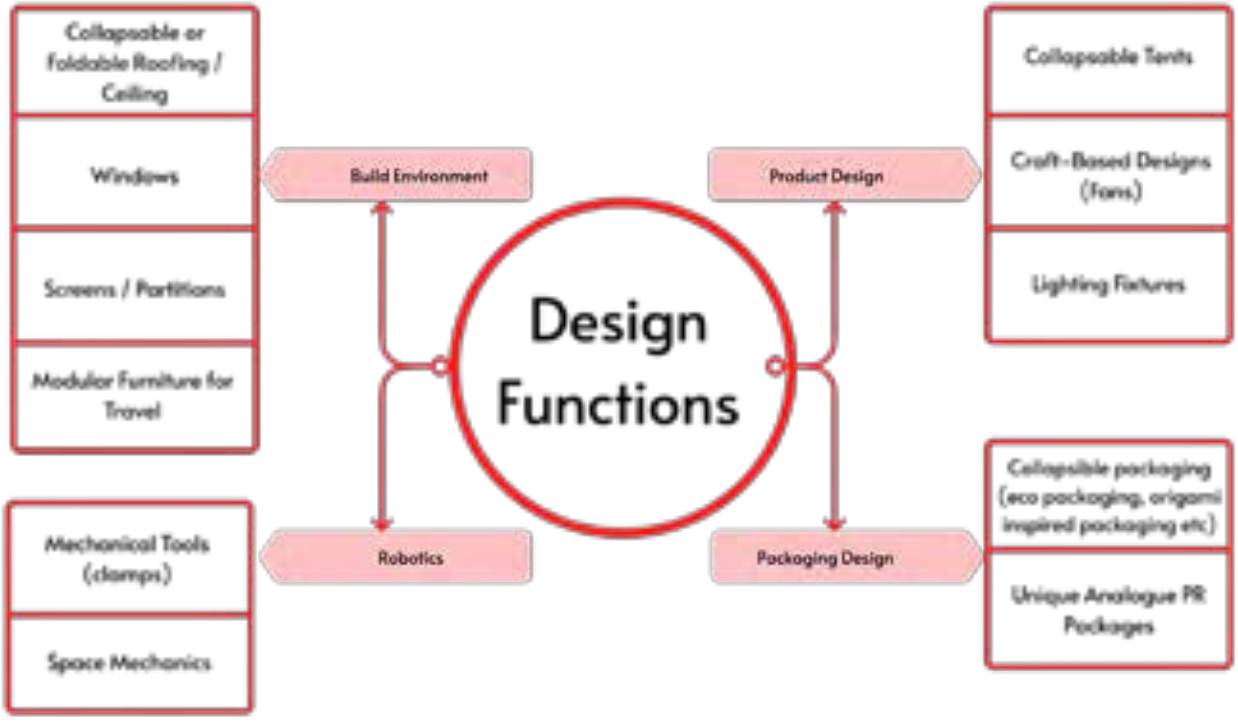
Mechanism

Earwigs have unique wings that spread out without the use of any muscles. Their wings encompass a natural folding pattern fit for flying strength and flexibility; made up of complex joints structured to open up and self-fold instead of using muscles.

The folding structure of the wing resembles a folding fan made using the Japanese art of origami. The wing is divided into a stiff outer and a more flexible inner region, with the leading edge supplying some stiffness from the base to the wing tip. When locked open, earwig wings store energy in the springy resilin joints.

Design Principle

Lightweight materials can be used to create physically strong systems.



Name

Lotus

Genus

Nelumbo Nucifera

Strategy

Folding structure & wax micro-scale bumps allow for surface self-cleaning

Function

Protection from Excess Liquid & Debris

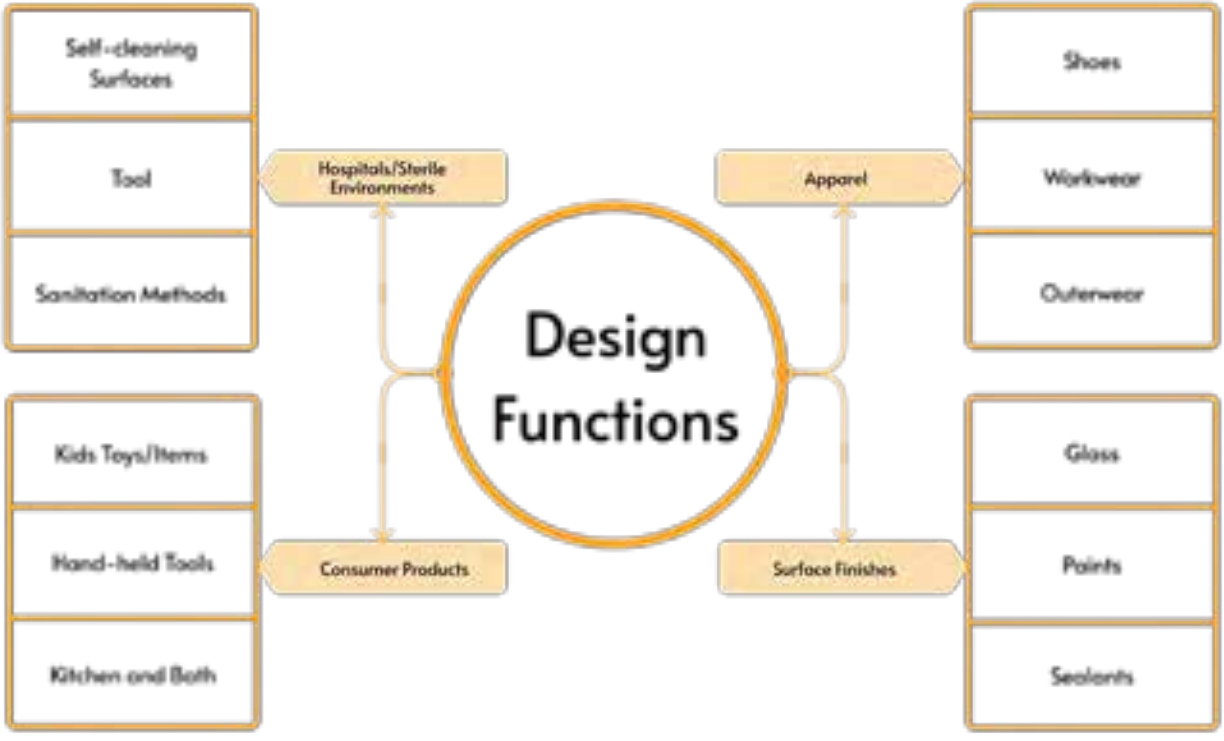
Mechanism

Sacred lotus leaves have a rough superhydrophobic micro-scale surface cause by both the use of papillose epidermal cells to create folds, and wax crystals forming micro-scale bumps. When a droplet of water falls onto the surface of the lotus leaf, the air trapped between each waxy bump, in the valleys, causes the water bead up and prevents it from wetting the surface.

The surface of the sacred lotus is not only hydrophobic, but superhydrophobic. Each wax crystal that makes up the bumpy surface contains nano-sized hairs. This helps create even more air gaps allowing water molecules to bead up even more successfully. Because water is more attracted to solids than gases, as the droplets bead up and roll off, any debris on the surface of the leaf will adhere to the water and be washed off.

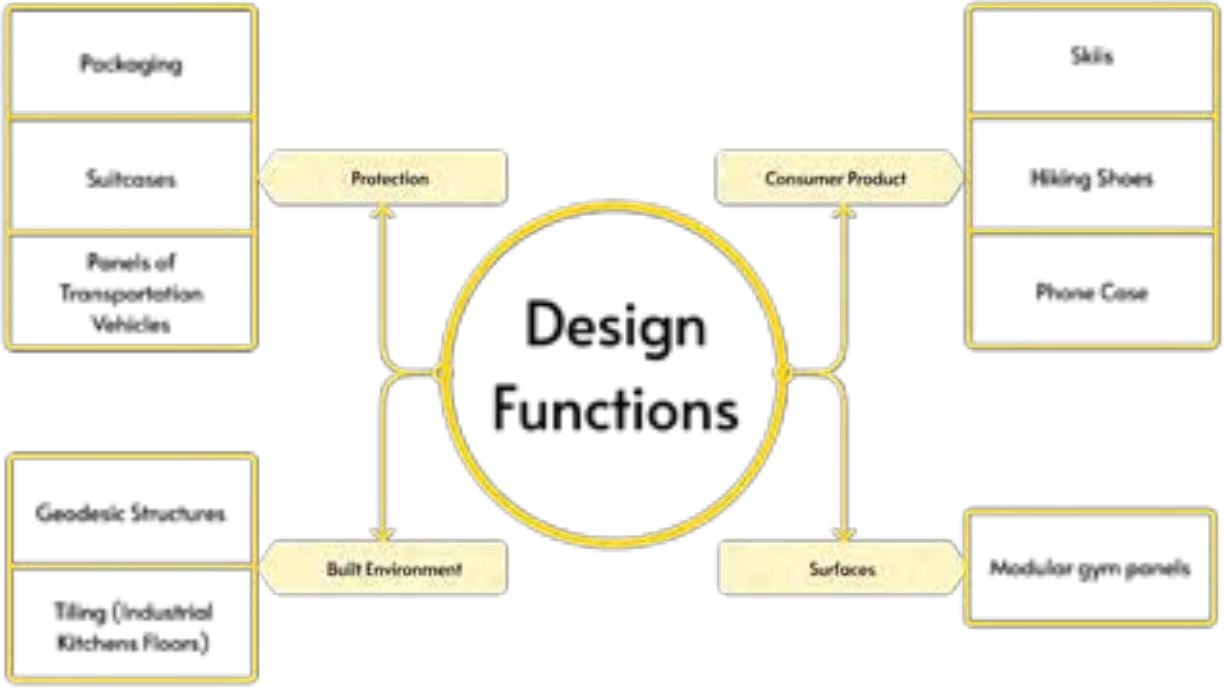
Design Principle

A self-cleaning surface can be achieved through texture and material.




SCAD


Name
Tortoise
Family
Testudinidae
Strategy
A multi-layered shell provides more opportunity for protection through alternating strength & flexibility
Function
Manage Impact, Protect, & Flex without tension
Mechanism
Tortoises have a unique way of protecting themselves from harm in the form of a multilayered shell.
The exposed layer is made up of hard, keratin-based hexagons, pentagons, and irregular shapes. The hexagons allow for tight packing, like puzzle pieces, while the surrounding pentagons allow for a tension-free bend as the dome shapes. Beneath the shapes (or "scutes") is a strong bone plate that protects the tortoise from predators with a proclivity to puncture.
The inner layer is made of a mesh-like material that is able to prevent excessive damage by absorbing pressure. The mesh-material has its own sections that interlock with each other, acting as 'joints' and allowing more room to bend.
Design Principle
A multi-layered surface of tightly-packed shapes & cushioned material provides protection & durability.


Design Functions
Protection
Packaging
Suitcases
Panels of Transportation Vehicles
Consumer Product
Skiis
Hiking Shoes
Phone Case
Built Environment
Geodesic Structures
Tiling (Industrial Kitchens Floors)
Surfaces
Modular gym panels

Name

Lichen

Genus

Lecanora Conizaeoides Lichen

Strategy

Pores on the surface allow gas to pass while the hydrophobic rough surface repels water

Function

Protects from excess liquid

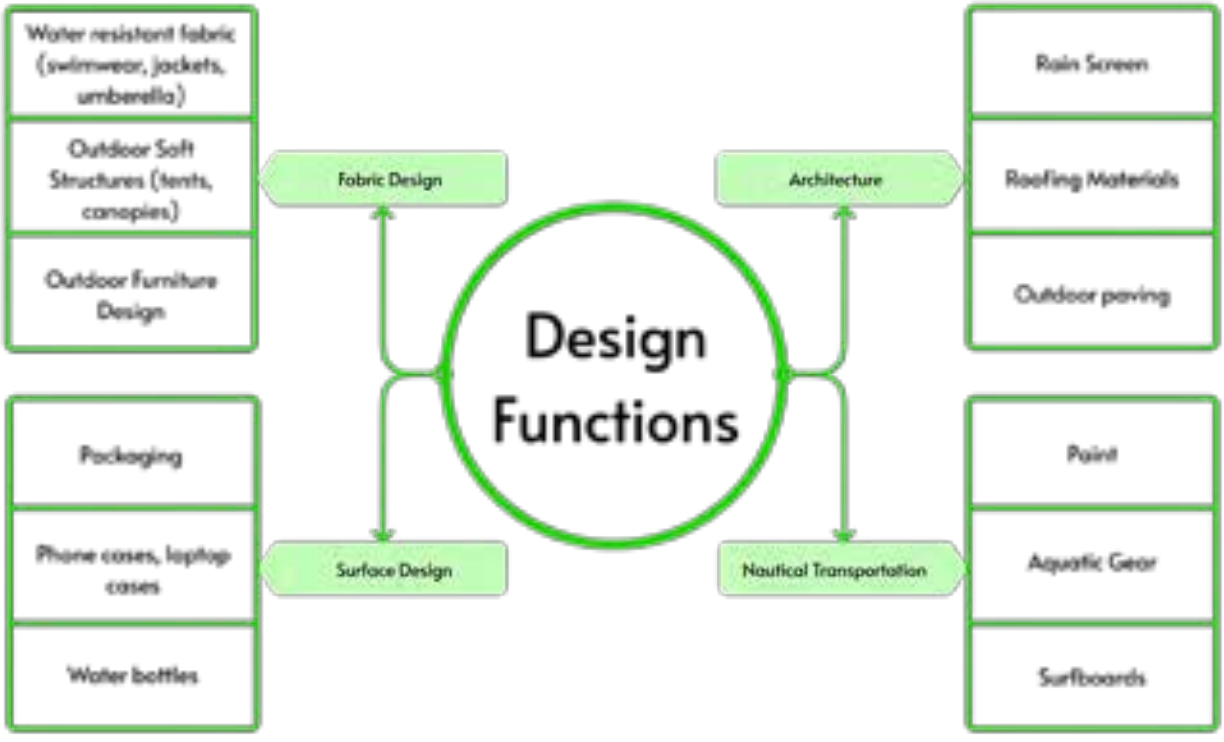
Mechanism

Most species evolve to survive, and this specific genus of lichen has done just that to survive acid rain.

The rough surface of the lichen creates an uneven surface texture; when rain falls, the water molecules sit upon the outermost part of the lichen's rough, multi-layered surface. Below these top layers sit micropores that are coated in hydrophobic compounds.
Through this design, openings are created that allow gasses to flow freely while actively preventing water from penetrating the surface.

Design Principle

Through texture, breathable surfaces may resist liquid saturation.



Name

Ferns

Genus

Begonia Pavonina

Strategy

Thin, Iridescent Layer Provides Photoprotection

Function

Protection from Light, Regulation of Cell Processes, & Filtering of Energy

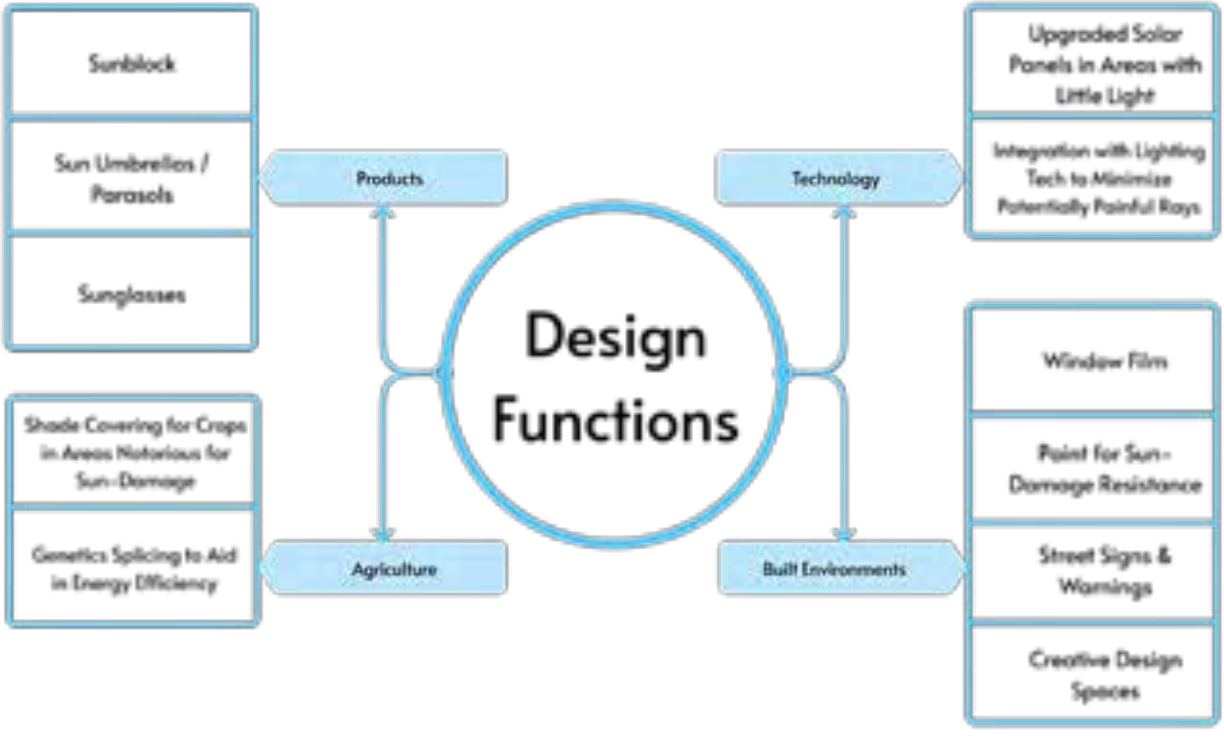
Mechanism

Surviving with minimal light on the floor of the rainforest is quite the feat, but this variation of Twinsorus Ferns (the B. Pavonina) has developed a great solution. Unlike the thylakoid stacks of chloroplasts in most plants, those in B.P. are arranged with precision, resulting in their iridescent color. This arrangement causes blue wavelengths of light to be reflected and act like a dense crystal; in other words, the light entering the B.P.'s chloroplasts is physically slowed down.

This effect is known to quantum physicists as "slow light;" this slowing down allows the plant more time to absorb what little energy it can intercept, increasing efficiency

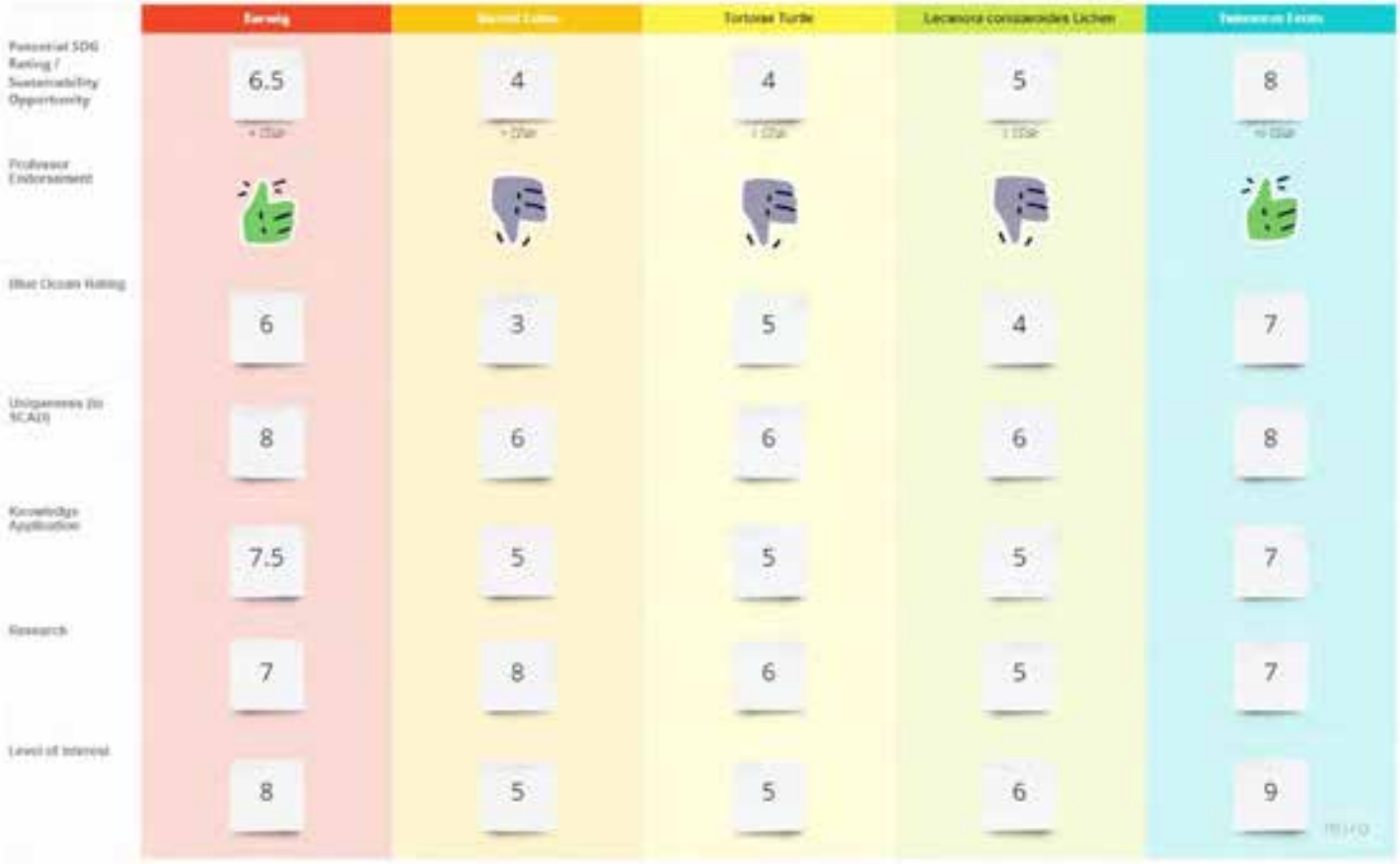
Design Principle

Color-based constructive interference may slow damage from UV rays.



We devised the design matrix in order to access the potential applications to curate a design solution, based on available research for each species and the design relevance to our backgrounds. However, at this stage we found them all still rating fairly high on our matrix.

Our next step was to further categorize into a more detailed matrix for evaluation, which we then used to vote on each species. This process finally led us to our chosen species which is the ***Begonia pavonina.***



Begonia pavonina

The *Begonia pavonina* -- also known as the *"peacock begonia"* -- is one of over 1,500 species of *Begonia* but has a single unique characteristic: its blue iridescence. The discovery of the *Begonia pavonina* was first published in the journal of the Malay States in 1909. That being said, the plant wasn't cultivated at all until the *Begonia grandis* was pursued.The plant can grow to about 16" in height and 8" wide, with leaves growing to between 4 & 6". The plant can be found in the biodiverse tropical rainforests of Mainland Malaysia among several thousand species of vascular plants and 2,000 species of trees. The *Begonia pavonina* in particular can be found on the forest floor, deep beneath the dense canopy with limited sunlight. Its blue iridescence is a unique evolutionary adaptation that has allowed it to extract extra energy from the dim light provided, allowing it to survive in the most unlikely of circumstances. This species flowers all year round, thriving in conditions between 55-95°F with high humidity. Given the right circumstances, the *Begonia pavonina* can live for up to 30 years without trouble. It is a monoecious species (meaning that it has both male and female reproductive organs, allowing it to reproduce as needed).

This specific *Begonia* is known to be a rhizomatous plant, growing a long red stem from thick rhizomes that grow along the soil's surface. Their flowers are classically pale pink and usually form in pairs from long stems. Predators of the *Begonia pavonina* are few and far between since all its parts are toxic when ingested by both humans and animals. No species (that we know of) has been able to develop the needed enzymes to allow the *Begonia pavonina* to be ingested because the foliage is embedded with insoluble oxalate crystals which are incredibly toxic. One species in particular has a special relationship with our *Begonia pavonina*: the Endo-mycorrhizal fungi. After coming in contact, the Endo-mycorrhizal fungi forms a structure inside the plants root system; the roots actively provide carbohydrates that the fungi thrives on, and the fungi transfers nutrients and water to the plant roots. Needless to say, this is the epitome of a symbiotic relationship.

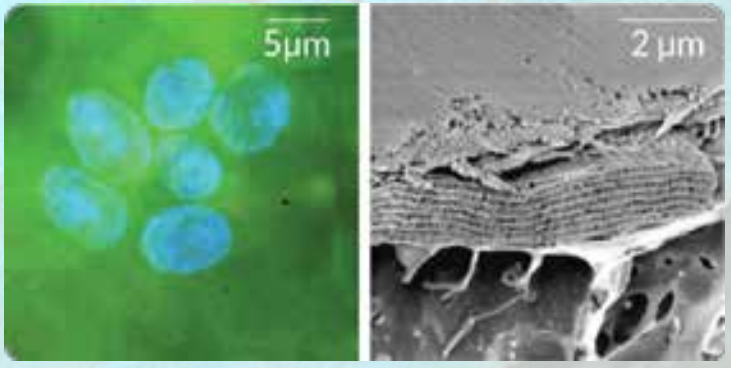
3 Main Functions

To capture, absorb and filter energy

To protect from UV damage

Regulate cellular processes

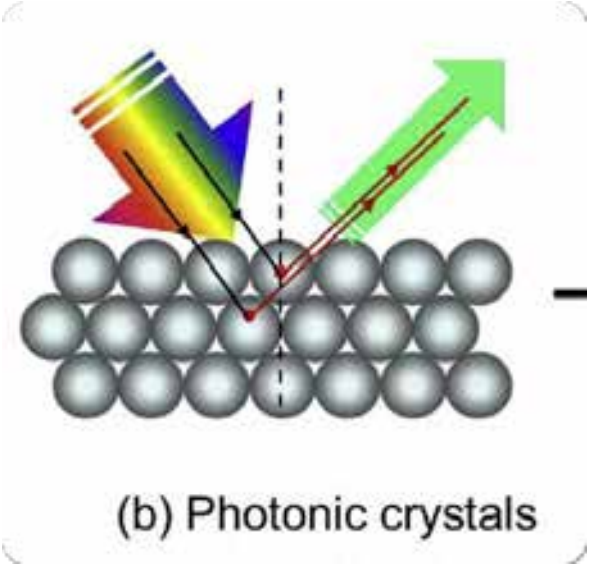
To understand how the *Begonia* performs these functions, it's essential to first understand this species at the cellular level.



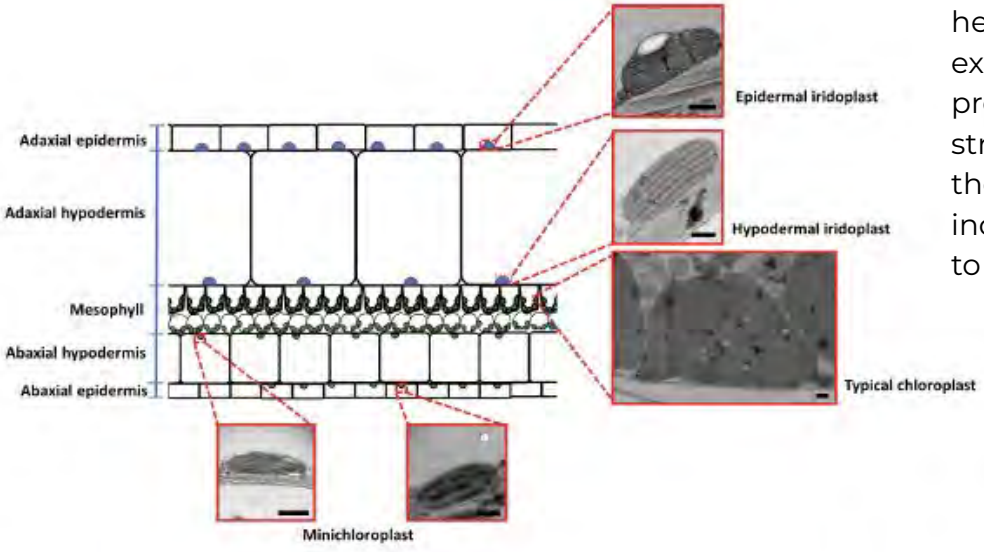
Unlike classic plants, the *Begonia pavonina* has developed iridoplasts: highly specialized chloroplasts that have adapted to thrive in tropical forests under low-light conditions. These iridoplasts are made up of multilayered membranes which are called thylakoids. This stacked structure acts as a dense crystal, slowing the rate of incoming UV rays, employing the quantum physics term called "slow light." The densely stacked thylakoid structure also interferes with light wavelengths, reflecting back the color that we see as iridescent blue.

Capture Absorb and filter energy

This slowing absorption of incoming light allows the plant to store the incoming energy under low-light conditions more efficiently- increasing photosynthesis up to 10%. In instances where there is enough light that makes it to the forest floor, the *Begonia pavonina* leaves use its classic chloroplasts to achieve photosynthesis normally. With both types of cells, the plant can successfully achieve photosynthesis in most conditions.

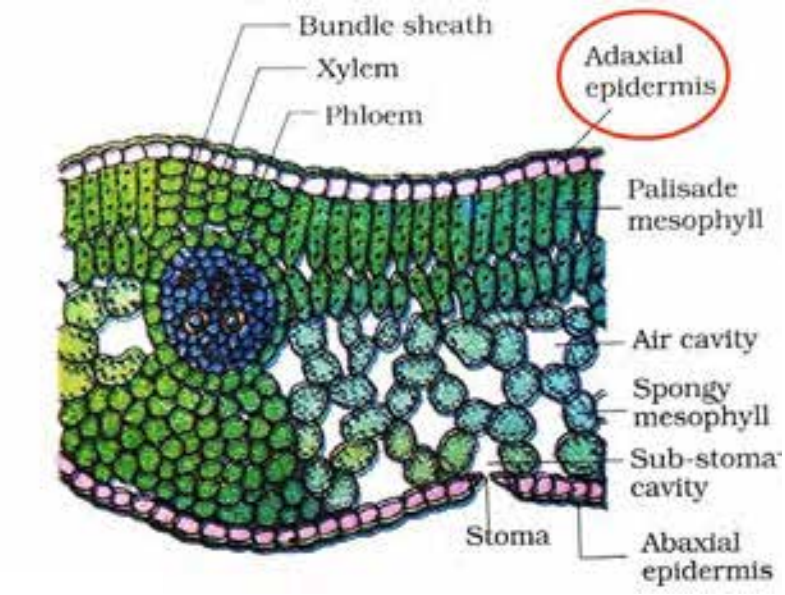


Protect from UV damage



The *Begonia pavonina* can also heal in tandem as it's being exposed to damaging rays, overall preserving its existing cell structures and saving resources in the long-run. The slowing of incoming light gives it more time to repair UV damage.

Regulate Cellular Processes



Many theories have been attributed to the *Begonia pavonina* hydrophobic properties; among some of the theories are its uneven surface (preventing microorganisms to grow), but one that mirrors the structure of the plants cells is their concave nature under a microscope. This feature of the adaxial epidermis has been proposed as a feature of many understory plants, preventing water and other debris from gathering on the surface.

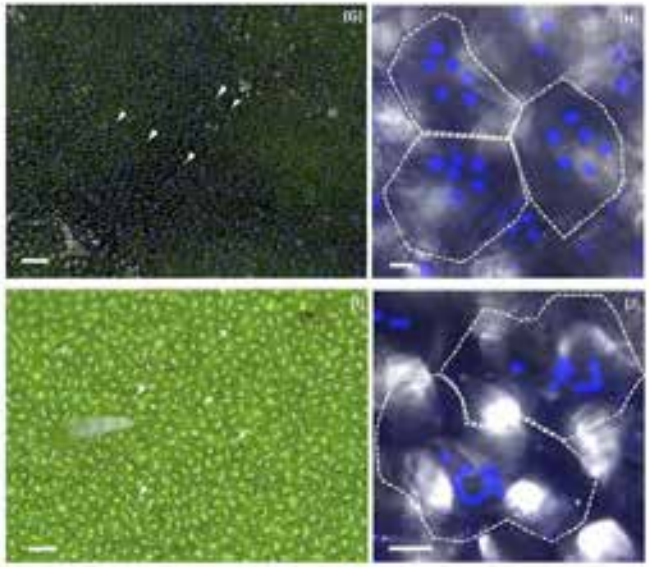
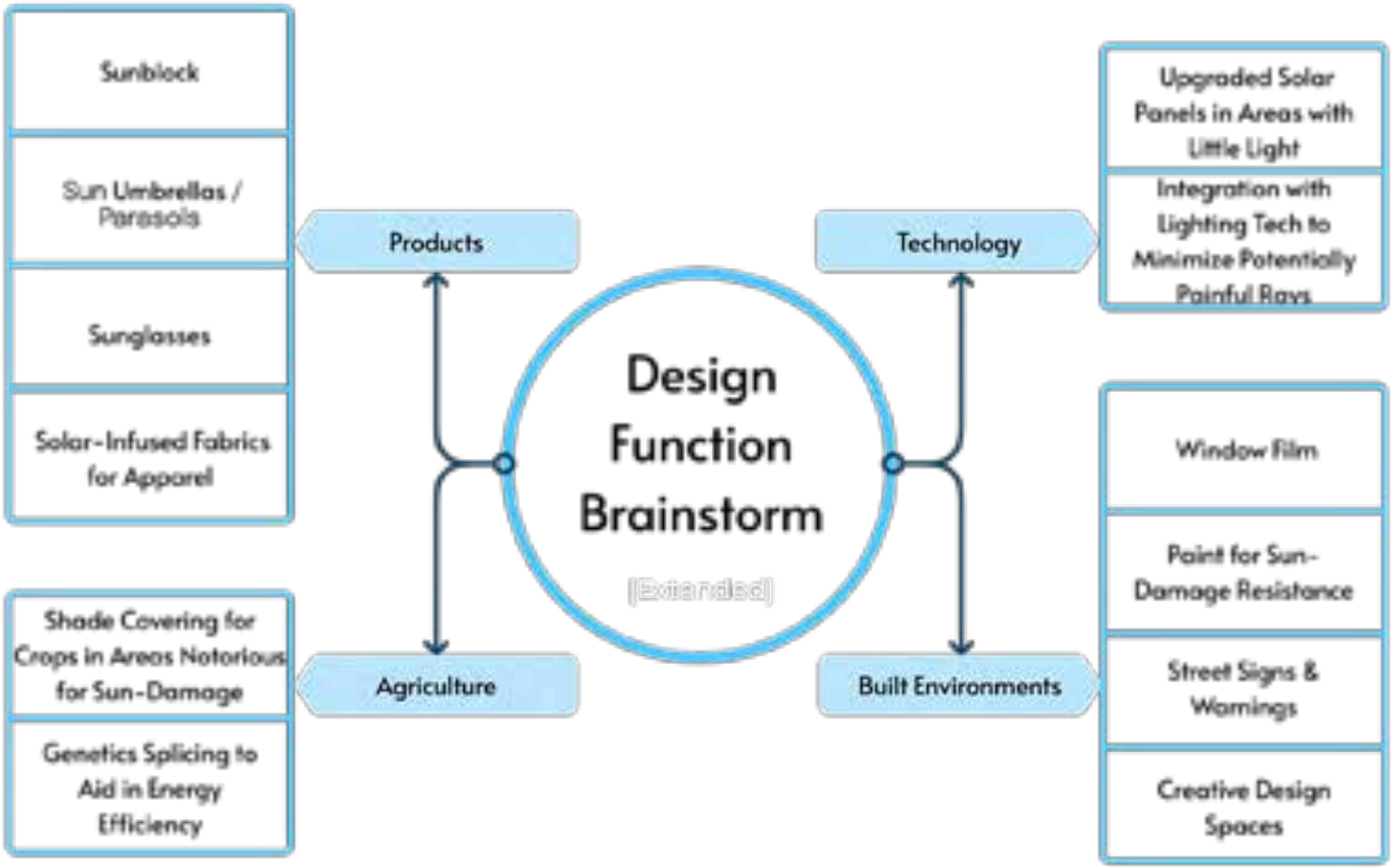


Figure 2.4 Photographs of adaxial surface of visually iridescent leaves of representative *Begonia* observed under epi-illumination stereoscope. (Continued)

This hydrophobic property may exist for a number of reasons, but a possible advantage to a dry surface may be that it reduces the opportunity of dusty substances that would otherwise prevent sunlight from accessing the leaf, or it may prevent water from beading up on the surface, creating a convex bubble that would intensify the UV rays.



DESIGN PRINCIPLE

Structural interference can redirect resources for various functions.

II

Considering Application

Current Research: Initial Case Studies

Context Brainstorm

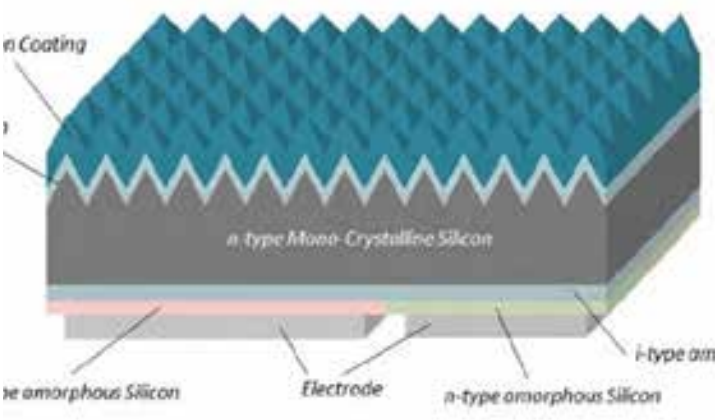
Evaluation Matrix

Taking from our design function brainstorm, our team researched products, technology, and the agricultural industry to identify real-life solutions that are similar to the functions of the *Begonia pavonina*. The three overarching functions are to capture, absorb and filter energy; protect from UV damage, and regulate cellular processes.

Solar Cell Optimization

H.E.A Efficiency

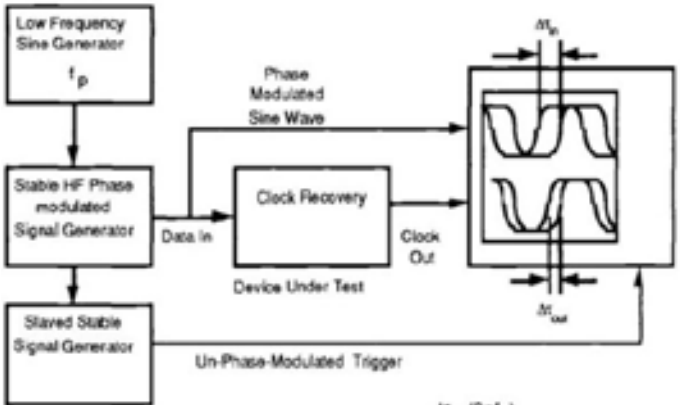
Starting in 2012, major developments and improvements were made in the structure of solar cells. Absorption of light in silicon within thin film solar cells was enhanced by at least 10% by the optimization of slow light in those cells. Essentially, as the photocurrent is improved, more light stays within the cell, and less refracts back into the atmosphere. Employing this technology in solar panels on a wide scale would improve our overall solar harvest by an enormous amount.



Telecommunications

H.E.A Efficiency

There has been very rapid progress in the past few years in improving the bandwidth of slow light and in transitioning the technology to telecommunications wavelengths. One of these technologies can be found in high-speed telecommunication regenerators for resynchronizing the data stream with the clock, which runs at a slower rate. As data communications rates climb, clock recovery and synchronization becomes more difficult using conventional electronic circuits.



Dropel Fabrics

Hydrophobic Properties

Dropel Fabrics is a company based in New York that uses nanotechnology to add a hydrophobic coating to fabric at a molecular level. Most hydrophobic materials are made with synthetic fibers, however Dropel transforms a natural material-cotton- to achieve this desired function.

Solar Sharc®

Hydrophobic Properties

Solar Sharc® has developed a durable, highly repellent coating for solar panels, which will reduce the need for cleaning & maintenance in the long run. The spray is cost-effective, more efficient, and easy to apply to existing structures. That being said, it's not chemically safe, not sustainable, and doesn't explicitly mimic the hydrophobic structure of the *Begonia pavonina's* cells, instead opting to achieve the same end result through chemical means.

Conclusion of Findings

After this initial research, we found that there were solutions abound for the content we wanted to explore, but nothing really spoke to us in the way we had hoped. Our *Begonia pavonina* had an amazing talent for being a complete system, able to perform many different activities at once. These imitations, however, only focused on a single function.

If we sought to completely honor the inspiration we've taken from our species, we would have to expand our point of view and look into not just one of its functions, but how they work together as a whole to survive in even the most impossible of conditions.

Matrix For Evaluating Impact of Opportunity Areas

Context	Opportunity	UV D.P. Prop.	H.E.A.E. Prop.	Hydro. Prop.	2nd Nat. Insp.	P. A. / Sus. Win	Level of Impact	SDGs Addressed
Technology	Upgraded Solar Panels	Yes	Yes	Yes	Tortoise: Damage prevention & layering	Access to solar energy in areas with little light	High	3, 7, 9, 11, 12, 13
Technology	Integration with lighting tech to minimize potentially painful rays	Yes	No	No		Increased wellbeing of those who come in contact with fluorescent lights	Medium	3,7, 9
Built Environments	Window Films	Yes	No	Yes	Lotus: hydrophobic and self-cleaning surface	UV damage within homes	Medium	9
Built Environments	Paint for sun-damage resistance	Yes	No	Yes	Lichen: breathability with hydrophobic properties	Reduction in need for reapplication of harmful paint	Low	9
Agriculture	Shade coverings for crops in areas notorious for sun-damage	Yes	Yes	Yes	Earwing: kinetic unfolding properties of Earwig wings	Providing opportunities for better health, income and environmental growth.	High	1, 2, 3, 9, 11, 12, 13, 15, 17
Agriculture	Genetics splicing to aid in energy efficiency	Yes	Yes	Yes		Integration of new consumable plant-life that is hyper-strong	Medium	7,9,15
Products	Sun umbrellas/parasols	Yes	No	Yes	Earwing: kinetic unfolding properties of Earwig wings	Easier access to UV damage preventing products (cancer prevention)	Medium	3, 9, 12
Products	Solar infused fabrics for apparel	Yes	Yes	No	Lichen: breathability with hydrophobic properties	Wearable solar panels that carry low charge for emergencies	Low	3,9,12

Our next step was to conduct a matrix for evaluating the impact of the opportunity areas identified in the design function brainstorm. From the insights we gained in our initial case studies, it was evident that we wanted a more overarching context that could allow us to apply our design principle- *structural interference can redirect resources for various functions* - in the most advantageous way. We found the agricultural and product context would not only reach all of the Begonia's functions, but it also has the potential to reach several Sustainable Development Goals in the process.

Initial Context & Design Criteria

Who: People from underprivileged societies in arid conditions with little access to fertile land for agriculture.

What: A large-scale modular shade-covering for crops in arid conditions, functioning as protection and a means of gathering solar energy.

Why: To help people from underprivileged communities grow their own food, create jobs for them and give them the opportunity for a more stable life.

Where: Areas with arid conditions and little access to fertile land.

How: Using structural interference to redirect light for sun protection.

Non-fertile land in arid conditions:

A little over 50 million square kilometers of the land on Earth is farmland, not all of which is capable of supporting crops. Farmable land could be halved by 2050 and every time the temperature rises one-degree Celsius, wheat yields could fall by 6%, rice by 3%, and maize by 7%. To increase food production to feed the future world we will need to find ways to farm poorer land in harsher climates—and do it sustainably.

Soils of arid lands are generally low in organic matter and range from slightly acidic to strongly alkaline on the surface. In many places the accumulation of calcium carbonate in the upper parts of the soil creates harded top soil that is hard to till. The calcium carbonate layers can be up to 90 m thick and virtually impervious to water.

Farming in Arid Conditions:

Farming can be very difficult in dry or unfertile conditions. One of the oldest methods to overcome this obstacle is crop rotation. Essentially, unfertile land is kept fallow. In this process the soil is aerated and plowed but unsown to restore fertility. To speed up this process, one can plant native species, use grazing animals to naturally fertilize with manure, or plant legumes as “cover crops” to help bring nitrogen back into the soil. Genetically modified crops can also help reduce toxicity in the land. Another method to restore unfertile land is using methods of composting Microorganisms are used, in addition to soil aeration, to revive soil over time. The Sahara Forest Project uses clay nanoparticles, mixed with desert sand, to create fertile plots where previously unable. This technique does remain very expensive. Another common farming technique in difficult agricultural conditions is something called agroforestry. This approach uses trees or shrubs to surround crops to help restore used land.

Who is Primarily Impacted?:

People are undernourished and do not have access to adequate food and 3 billion people cannot attain healthy diets, that's 30% of the world with no access to healthy diet options.

Conflict, climate variability and extremes, and economic slowdowns and downturns are the major drivers slowing down progress, particularly where inequality is high.

418 Million In Asia

282 Million in Africa

60 Million in Latin America and the Caribbean

Existing Solution (Case Study)

Sundrop Farms

Sundrop Farms is an International arid climate Agribusiness that grows crops in energy efficient greenhouses that turn seawater and sunlight into energy and water. This is achieved by using the sun's energy to yield freshwater for irrigation. That is then turned into electricity to power the greenhouse to heat and cool the crops. This solution omits the dependence of soil to grow and produce crops.

Projected Prosperity

Although it's difficult to predict the outcome of our project at this stage, it would be remiss of us not to consider the possible end-goal: an improved life for those most-affected. While there are people all around the globe affected by food shortages, we chose to focus on the United States as it can be used as a scalable model to be applied globally.

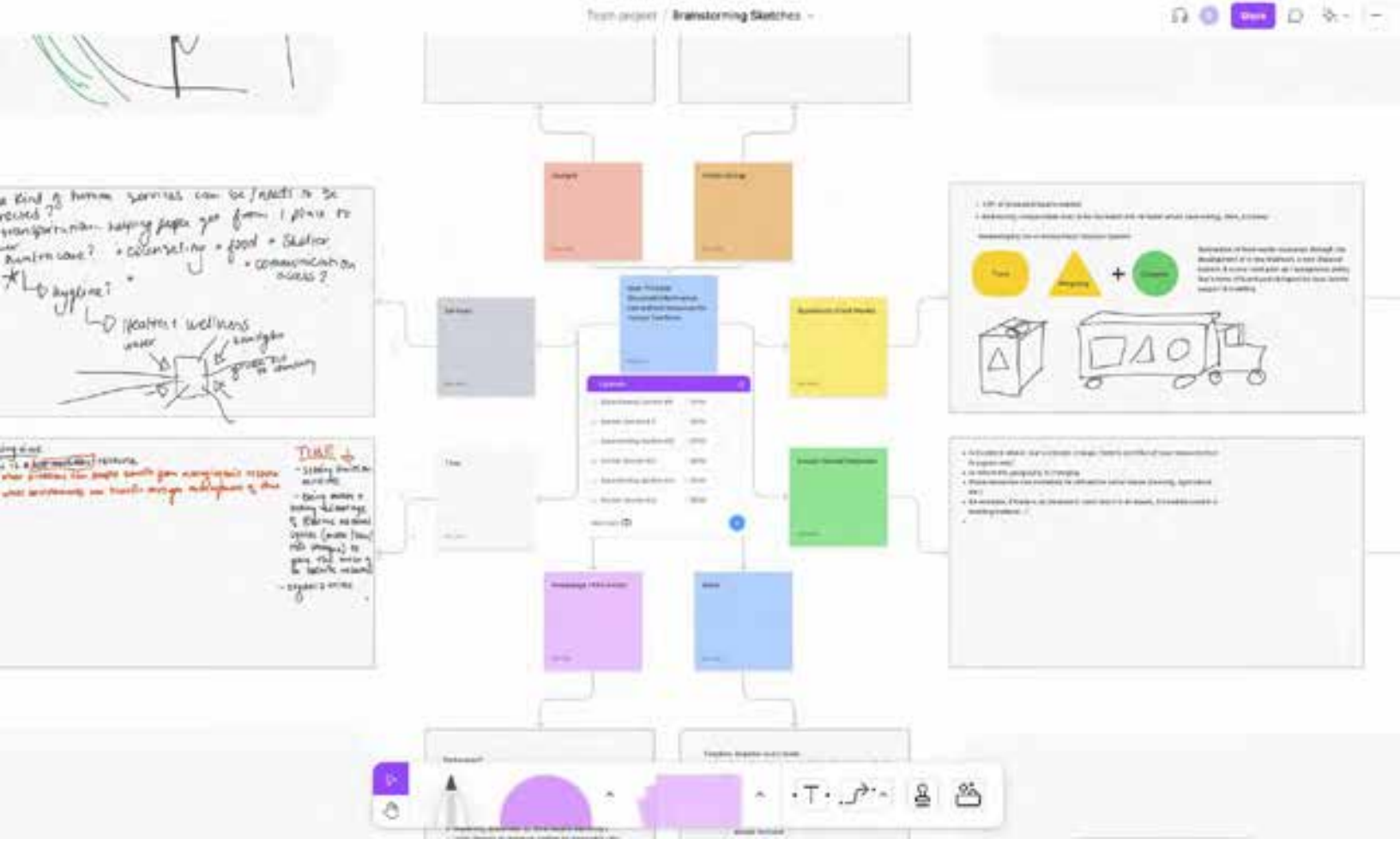
Feed
760 million+

Provide
Accessible
Power

Improve Overall
Livelihood

PHASE 2

Taking Root



Brainstorming Sprint

Now that we had a fairly solid idea of what we wanted to focus on, it was time to do some brainstorming, and very intensive brainstorming at that. We conducted a brainstorming sprint activity, focusing on the prompt of “what types of resources can be managed, and what services can be developed as a result?”

Concepts were sketched, discussed, and developed, all coming to a peak as we discovered that agriculture was certainly our best bet to impact the most lives and most honor the complex system the *Begonia pavonina* created.

Modern US Agricultural Practices

Agriculture, food, and related industries contributed $1.109 trillion to the U.S. gross domestic product (GDP) in 2019, a 5.2-percent share; this is a considerably large portion, but it doesn't hold a candle to the fact that food accounted for 11.9% of U.S. households' expenditures in 2020. Not only that, but agriculture and its related industries provide 10.3% of U.S. employment.

$1.1 T

Contributed to the U.S GDP

10.3%

U.S Employment

11.9%

Food-based Expenditures in 2020

Although this may seem like a large percentage, when it comes to sheer volume and capability, family-owned farms share only a small portion of the market. Family farms are able to pass on their understanding of local soil conditions and weather patterns to their successors, but that can only carry them so far; most small farms make only $350,000 a year before costs, a fairly small amount considering the amount of work involved.

2.05 Million

Farms in the U.S

97%

Of farms are family-owned

Industrial Farming

The majority of farming is dominated by large, industry farms, each of which make upwards of $1 million yearly. In order to boost their efficiency, most industrial farms focus on a single row crop that can be harvested by machines; this practice is called monoculture, and it's incredibly cost effective, but it negatively impacts the local environment and the soil's health, forcing the farms to use chemical fertilizers, pesticides, and feed additives to boost production.

3%
Of farms are large/ Industrial

1 + Million
Yearly Income

Monocultural
Single Crop Focus

Sustainable Farming

The practice of sustainable agriculture incorporates environmental, animal, and farmworker well-being to create a truly profitable business model, in more ways than one. Methods it uses have been proven to reduce pollution levels, minimize water use, and improve soil health. The practice maintains the name "sustainable agriculture" for this exact reason; it doesn't degrade our available natural resources necessary for future farming & prosperity.

Some methods explored within this practice include more traditional methods, such as crop rotation and avoiding the use of monoculture crops, both of which improves the health of the soil and protects the farmer from potential diseases or price swings you may encounter from a single-crop harvest. The soil can be further improved with cover crops, compost, mulches, and the incorporation of livestock into crop production.

Sustainable agriculture also relies on organic farming methods and renewable energy; by doing this, the overall burning of fossil fuels is dramatically reduced, not contributing to climate change, and limiting the potential for extreme weather, one of the largest threats to the U.S. agriculture industry in existence.

The Rise of Regenerative Agriculture

In the near future, our new U.S. administration plans to incentivize farmers to adopt climate-friendly practices that protect the environment. Tom Vilsack, U.S. Department of Agriculture Secretary, has been a vocal advocate for making “carbon banks” more accessible to farm operators; this would pay farmers to adopt cultivation techniques that reduce carbon emissions.

“I think agriculture is probably the first and best place to begin getting some wins in this climate area. Farmers are prepared for it. Farmer’s are anxious to do it.” -Tom Vilsack

Conservation Cultivation

In our current era, our carbon market is considered to be a bit of a “wild west;” though regulating the idea of a “carbon bank” to incentivize farmers to reduce carbon emissions, we can create a structured incentive system that truly measures carbon reduction and then rewards it.

This agricultural initiative moving towards environmental stewardship is an amazing opportunity for farmers to adopt practices that will benefit the environment as a whole. For instance, based on a recent report by the American Farmland Trust, if 70% of cropland used just two regenerative practices, the impact would be akin to removing 53 million automobiles from roadways. Just like an ant colony, the combined efforts of the many create a true impact. This also highlights the importance of agricultural research funding, especially those climate-smart practices.

The Principles

Cover Crops

Crop Rotation

Minimal Tilling

The Future of Agriculture

"Despite continued challenges, markets are functioning well, and the food supply remains safe, abundant, and affordable. Commodity prices are strong, reflecting, in some cases, historically tight stocks and remarkably strong export demand in the face of rising prices."

- Seth Meyer, U.S. Department of Agriculture chief economist

Currently **climate change** is very likely to affect food security at the global, regional, and local level. Climate change can disrupt food availability, reduce access to food, and affect food quality. Increasing temperatures can contribute to spoilage and contamination. **More extreme temperature** and precipitation can prevent crops from growing. Extreme events, especially **floods and droughts,** can harm crops and reduce yields. Dealing with drought could become a challenge in areas where rising summer temperatures cause soils to become drier. **Many weeds, pests, and fungi** thrive under warmer temperatures, wetter climates, and increased CO2 levels. And the ranges and distribution of weeds and pests are likely to increase with climate change causing new problems for farmers' crops previously unexposed to these species.

The problem with the current state of the agricultural processes in place is that the negative effects from, exorbitantly wasteful, and unnatural methods of farming are being overlooked by government entities. People in power make it seem like the future of agriculture is somewhat "fine" and "promising" when in fact we are heading towards extreme weather, depleted nutrients, drought and W.P.F increase due to climate change.

The current crop spread in the United States: barley, corn, cotton, flaxseed, peanuts, rice, sorghum, soybeans, sugarbeets, sugarcane, durum wheat, spring wheat, and winter wheat

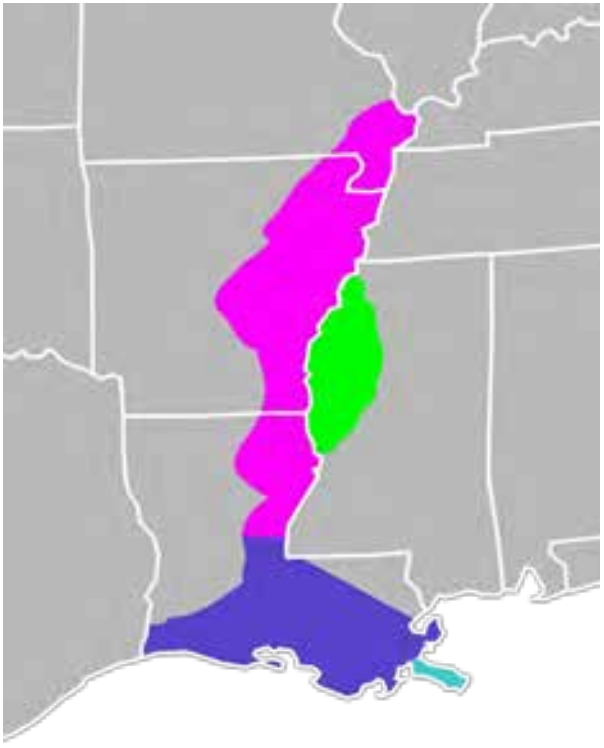
Current Crop Spread

Over 2/3's of the nation's vegetable and produce supply are harvested in California; normally this would be not be an issue, but California has a proclivity for climate-related catastrophe which means that in light of climate change there must be another supplemental area that could grow similar crops in slightly different conditions so our entire food supply system is not disrupted.

State	Farmland (acres)	Average Farm Size (acres)	Farms >5,000 acres	Total Market Value of Farms	Average Market Value of Farm
California	24.5M	348	923	$45.2B	$640K
Tennessee	10.9M	155	90	$3.8B	$54K
Arkansas	13.9M	326	227	$9.7B	$226K
Mississippi	10.4M	298	162	$6.2B	$177K
Missouri	27.8M	291	260	$10.5B	$110K

“New California”

Using the Mid-Mississippi Delta Region [Eastern Arkansas, Western Tennessee, Southeast Missouri, and Northwest Mississippi] would enable an existing rich farming tradition (which would mostly harvest row crops such as rice, soybeans, and corn) and leverage it to grow specialty crops. The region is already cultivating watermelon, berries, and tomatoes, but this could be heightened on every scale.

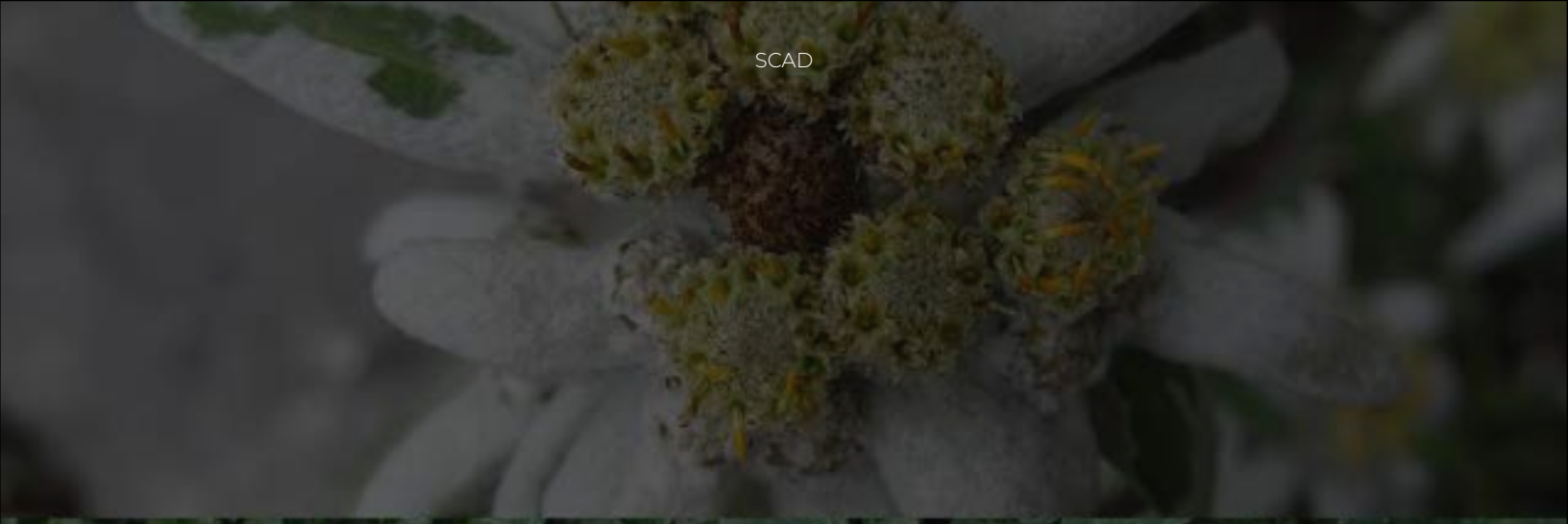


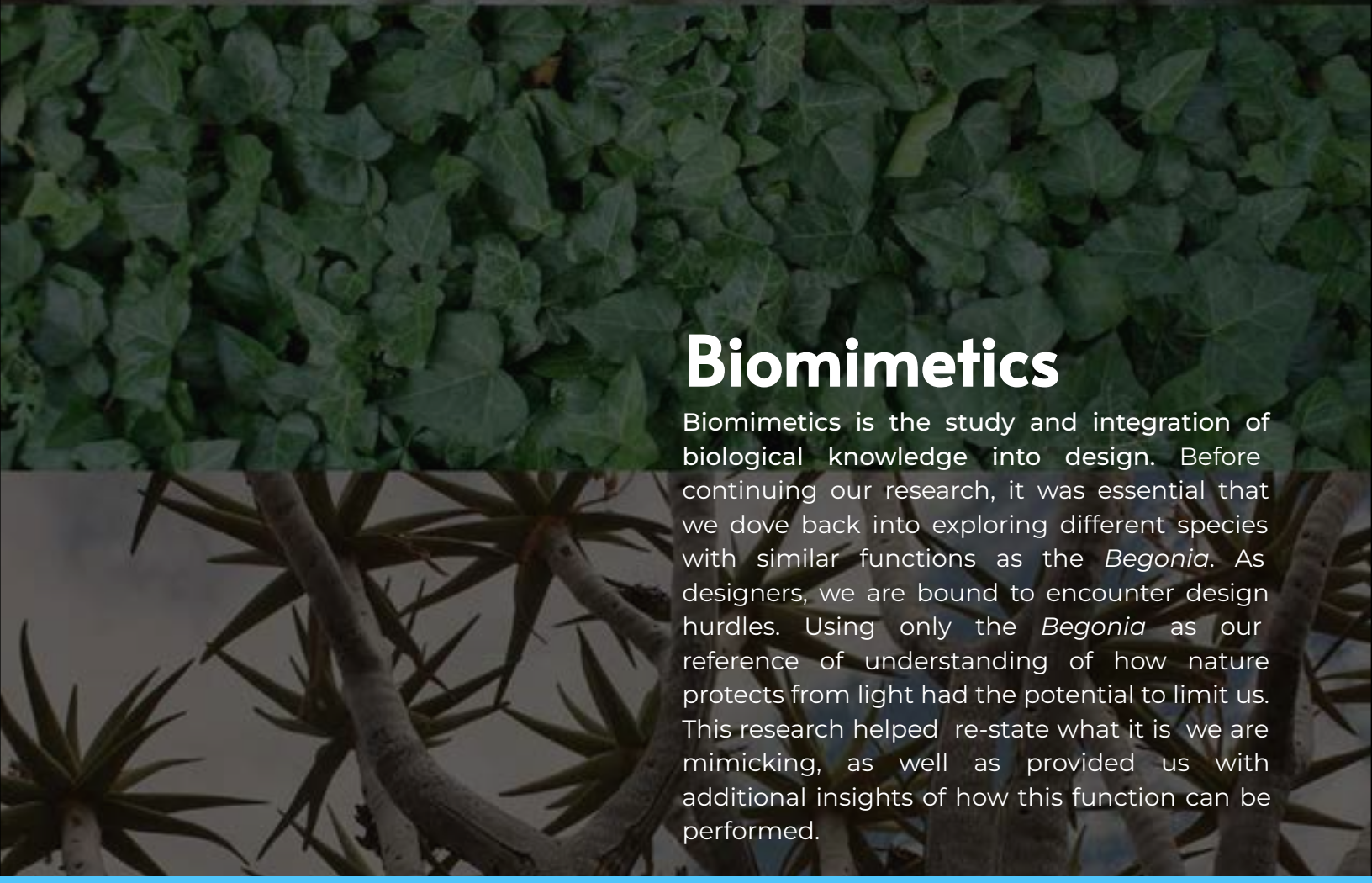
Specialty Crops

Research has been conducted to determine if the MMD region is capable of hosting these new specialty crops (including berries, kale, tomatoes, lettuce, and more), and the results have been a resounding success. Integrating this diversity of produce and region into the current supply would make the US food chain more resilient to disasters & give fresher produce to nearby regions at a lower price with less of a carbon footprint & waste.

Challenges and Opportunities

While the Delta region has a long history of farming (including some specialty crops), it also has a very different climate than California's Central Valley. Water is plentiful in the Delta and expected to remain so, but it also has a few key climate differences that will determine which crops can be grown at all and in a profitable manner (see above).





Biomimetics

Biomimetics is the study and integration of biological knowledge into design. Before continuing our research, it was essential that we dove back into exploring different species with similar functions as the *Begonia*. As designers, we are bound to encounter design hurdles. Using only the *Begonia* as our reference of understanding of how nature protects from light had the potential to limit us. This research helped re-state what it is we are mimicking, as well as provided us with additional insights of how this function can be performed.

Additional Species Research

Our team has identified three additional species that perform similar functions to our chosen species, the *Begonia pavonina*. This additional research will provide us with a more in- depth understanding of how the process is performed throughout nature.

Our team researched three species in particular: the Fan Aloe, Edelweiss, and Common Ivy. Each of these species protects from light through the various methods of reflection, absorption, and dispersion.

Fan Aloe (*Aloe pilactilis*)

Strategy:
The branches of a quiver tree are protected from the heat of the sun by a reflective coating of white powder.

Function:
Protect From Light

Fan Aloe's branches are covered in a fine white powder, which is responsible for providing a cooling property to the plant as it reflects the sun's heat instead of absorbing it. Heat can also escape through its thick leaves that grow in a succulent rosette form. This also reduces the amount of moisture lost by evaporation from the surface of their leaves.

Edelweiss (*Leontopodium alpinum*)

Strategy:
Hairs Absorb Ultraviolet Radiation

Function:
Protect From Light

Edelweiss is a small, white-flowered alpine plant that is native to mountainous European locations. The Edelweiss is a mountain flower, exposed to a large amount of ultraviolet light. A research team at the University of Notre-Dame de la Paix in Namur, Belgium measured the spectrum of light reflected from the plant and found that while most wavelengths are reflected, UV is not It is completely absorbed due to its hair-like fibers that grow 0.18 micrometers across which is close to the wavelength of UV light allowing it to be completely absorbed over them and preventing the penetration into the plant's body.

The Common ivy (*Hedera helix*)

Strategy:
Nanoparticles Block UV Light

Function:
Protect From Light

The common ivy has Organic nanoparticles which are secreted by the ivy's rootlets. These nanoparticles resemble a yellowish material which absorbs and scatters the UV light due to the leaf's large surface-to-volume ratio. The uniformity of the leaf allows the light to be partially soaked up and partially dispersed.

III

Focused Case Studies

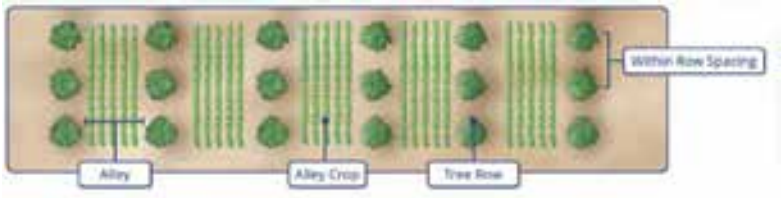
Agroforestry

Agroforestry is intentional integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits. There are 5 different types of Agroforestry: Alley cropping, Silvopasture, Windbreaks, Forest Farming, and Riparian Forest Buffers. Agroforestry has the potential to benefit not only crops, but farmers and their businesses as well.

5 Types of Agroforestry

Alley Cropping

This is the process of planting crops between rows of trees while the trees mature to ensure a steady income. The system can be designed to produce fruits, vegetables, grains, flowers, herbs, bioenergy feedstocks, and more.



Silvopasture

combines trees with livestock and their forages on one piece of land. The trees provide timber, fruit, or nuts as well as shade and shelter for livestock and their forages, reducing stress on the animals from the hot summer sun, cold winter winds, or a downpour

Forest Farming

Forest farming- also known as multi-story cropping is a method to grow food, herbal, botanical, or decorative crops under a forest canopy. This provides ideal shade levels and takes advantage of the natural environment.

Windbreaks

Windbreaks is a linear agroforestry practice that protects crops, animals, buildings, and soil from wind, snow, dust, and odors. This method is also referred to as shelterbelts, hedgerows, or living snow fences and has the potential to support wildlife and maintain a steady source of income.

Riparian Forest Buffers

Riparian Forest Buffers are natural or re-established areas along rivers and streams made up of trees, shrubs, and grasses. These buffers can help filter farm runoff while the roots stabilize the banks of streams, rivers, lakes and ponds to prevent erosion. These areas can also support wildlife and provide another source of income.

Pros

- Protect soil, animals, crop, and homes from extreme weather
- Increases product yield
- Improves water runoff conditions
- Provides habitat for wildlife
- Improves pollination
- Produce jobs
- Reduces greenhouse gases
- Can reduce global warming and sea level rise
- Purifies air

Cons

- Infrastructure / Implementation
- Lack of supply chains
- Financial
- High return on investment
- High start-up costs
- Lack of technical assistance
- Mainly affects small farms
- Uncertain land conditions

Agroforestry Case Study

Restinclières Farm

Restinclieres Farm located about 15 km north of Montpellier, France was looking to improve long-term productivity of their monoculture farming systems. Their objective was to research complex farming systems that could improve overarching farming practices. The farm conducted research of the long-term productivity of monoculture systems vs complex farming systems (specifically agroforestry and agrivoltaics).

What: Long-term productivity of monoculture systems vs complex farming systems (specifically agroforestry and agrivotaics).

How: The research measured the productivity of an agroforestry system for 15 years through the use of field monitoring, prototypes and numeric models. Productivity of an agrivoltaic system was also measured for 1 year through the use of numeric models that estimated long-term results. They used what's called the Land Equivalent Ratio to measure the efficiency of complex vs monoculture systems.

Results: Their results identified that complex systems are more productive than traditional monoculture systems. (AF LER of 1.2-1.5; AV LER of 1.3-1.6)

Complex systems are more productive than traditional monoculture systems.

Solar Energy and Protection

How Does the Sun Affect Crops?

Sunlight is critical for photosynthesis and plant growth; however, excess amounts can cause extreme heat stress which can lower the rate at which photosynthesis occurs and also dehydrate the plant. This in turn affects crop growth, development and yield. These heat-stress conditions account for an average loss in marketable yield ranging anywhere between 8-45%.

Agrivoltaics is an interesting solution to reduce heat stress on crops. This is a system that combines the use of solar panels and agriculture on the same plot of land. The benefits include providing shade for crops, increasing their performance and expanding growing seasons, reducing installation costs of solar panels, and diversifies the revenue for local farmers; for example revenue would be produced from food produced and also from selling power to local grids.

Further research shows that Agrivoltaic systems can increase global land productivity from 35-73%.

Agrivoltaics Case Study:

Colorado Solar Garden

This Solar Garden is a great example of agrivoltaics being implemented in Boulder, Colorado. This was a 50 year family-owned business that was previously used to harvest only alfalfa and hay. However, the farm was struggling to turn a profit and was steadily losing revenue.

Their solution was to replace the land with solar arrays, in hopes of selling power to local grids; however the land was designated as historic farmland. With the help of local researchers and schools, the farm decided to implement an agrivoltaic system, turning otherwise unused land beneath solar panels into a place to grow food. This not only preserved the farmland and produced marketable crops, but it also allowed him to sell power to the local grid. Additionally, evaporation from irrigation water keeps the solar panels cool-managing their efficiency.

1.2 Megawatts

Of power sold to the local grid.

50%

Less water needed by crops.

Flexible Solar Panels

Flexible solar panels are panels of metal, plastic or glass covered in one or more layers of thin photovoltaic film. This makes them a lot thinner, lighter and more flexible than standard solar panels. These features make flexible solar panels easier to move and install and can make them a better option for roofs which cannot support the weight of standard solar panels. the most efficient panels can reach up to 21% efficiency while the cheapest could only reach 13%. There are several types of thin-film solar panels which are made from different materials. Flexible solar panels are just one type and are made from silicon. Thin-film solar panels are generally less costly to buy than monocrystalline or polycrystalline as they are easier to produce. However they do not last as long as other solar panels and are wider than traditional panels so aren't usually recommended for installation on homes.

Pros

Wide range of applications: Flexible solar panels can be adapted to suit a range of different installations as they can be shaped to suit the surface. They are a great choice for caravans and campervans.

Lightweight: Flexible solar panels are lightweight and therefore better suited to roofs which can't take much weight.

Portable: They are easy to move from one place to another so are ideal for temporary installations.

Semi-transparent: Thin and flexible solar panels can be semi-transparent which makes them well suited for installation on glass or even as windows.

Less affected by weather conditions: Flexible solar panels are not as affected by heat or shade so can maintain a more consistent level of efficiency and do not need to be installed on south facing roofs.

Durable: Flexible solar panels are made from durable material so are resistant to adverse weather conditions.

Low cost: Flexible solar panels are cheaper to produce and install than traditional solar panels.

Cons

Lower efficiency: Flexible solar panels are not as efficient at converting sunlight into electricity as standard panels, although development is ongoing.

Take up more space: Because the layers of PV cells are thinner they need to be spread over a wider surface area and take up more space.

Shorter lifespan: While flexible solar panels are durable they typically have a shorter lifespan than standard panels.

CASE STUDY

ACSA Solar Panels:

ACSA's solar panel film is lightweight, flexible, semi-transparent, impact resistant, portable, and suitable for indoor or outdoor use on a large or small scale. ASCA is able to function at lower levels of light intensity than other technologies. The panels are completely customizable; they come in a variety of colors including blue, green, red, and gray. They can also have coatings added such as glass, plastic, composite or textiles to optimize its integration within different applications.

The ASCA film is an environmentally friendly organic photovoltaic innovation produced by a French Solar Company. ASCA technology offers significant environmental benefits and a short energy payback time (EPBT).

Some of the other specifications include:

Thickness < 400 µm

Power Up to 40 Wp/m²

Operating temperature -20 to +65°C

Storage temperature -40 to +85°C

Rainwater Irrigation

A rainwater irrigation system is the technology that collects and stores rainwater for human, gardening or farming use through rain water harvesting. Rain water harvesting can be done simply through barrels or through pumps, tanks or an **“irrigation system”.** Rainwater is healthier for plants because it does not contain salt or chlorine. Both salt and chlorine will dehydrate normal plants further. Rainwater harvesting systems range from simple rain barrels to more elaborate structures with pumps, tanks, and **irrigation systems.**

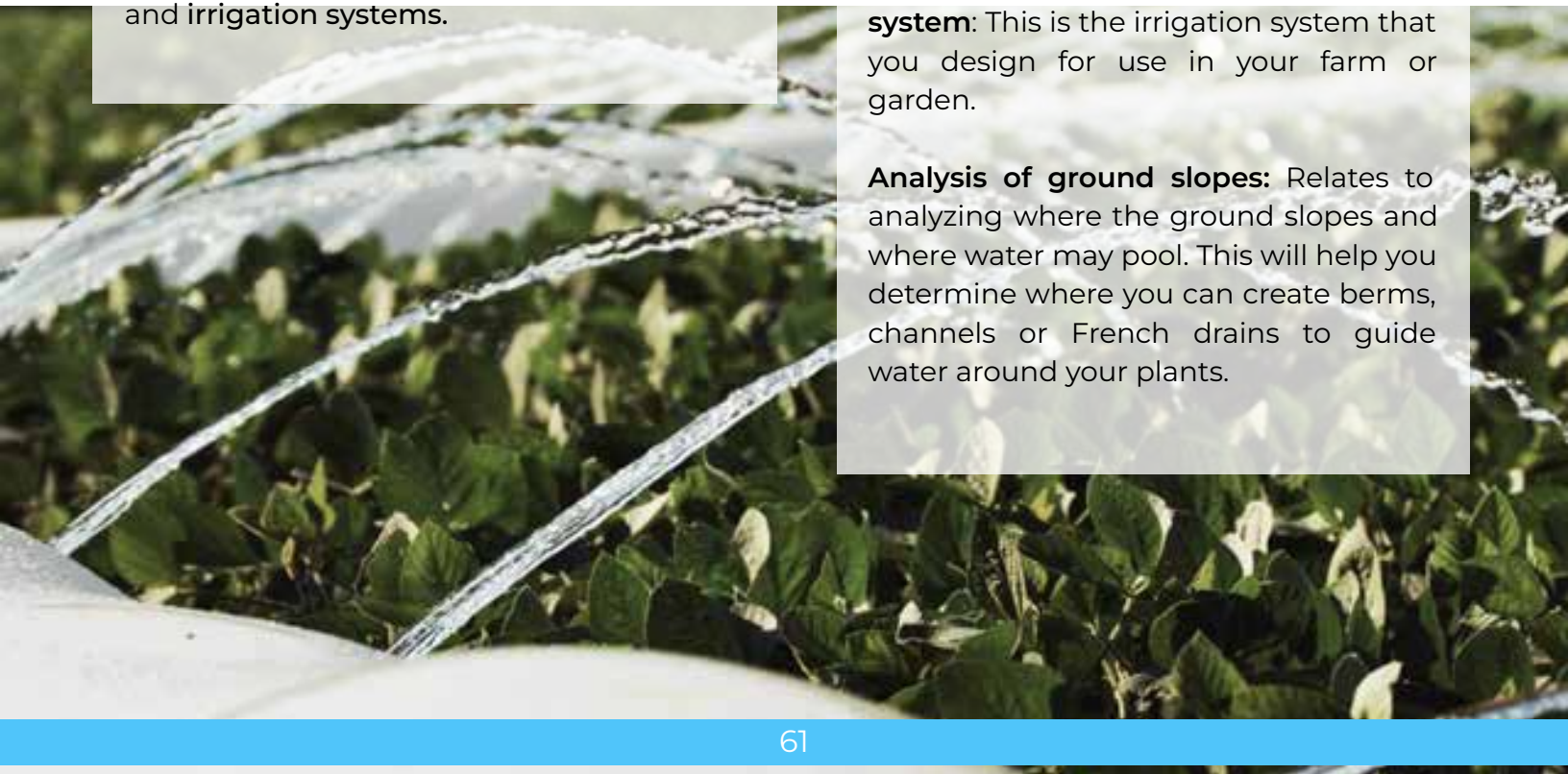
The basic requirements for a rainwater irrigation system include:

Rainwater runoff: This is the amount of rainwater that falls on an impervious surface and can be collected for use right away, or stored and saved for later use

Plant water requirements: This refers to the number of plants that one has; their age, size and how close they are planted together.

Water collection and distribution system: This is the irrigation system that you design for use in your farm or garden.

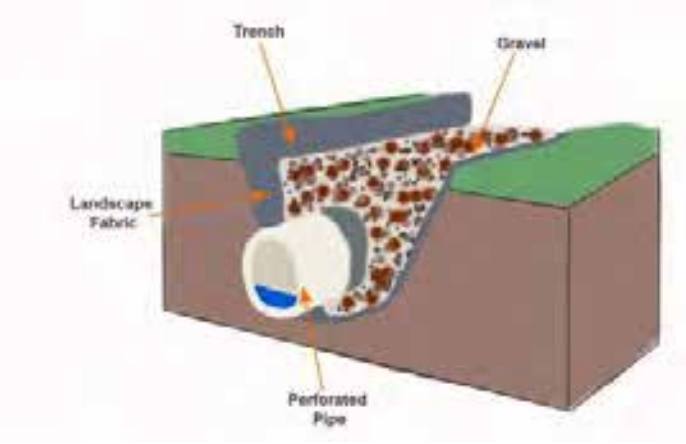
Analysis of ground slopes: Relates to analyzing where the ground slopes and where water may pool. This will help you determine where you can create berms, channels or French drains to guide water around your plants.



Ideal Irrigation systems for farming

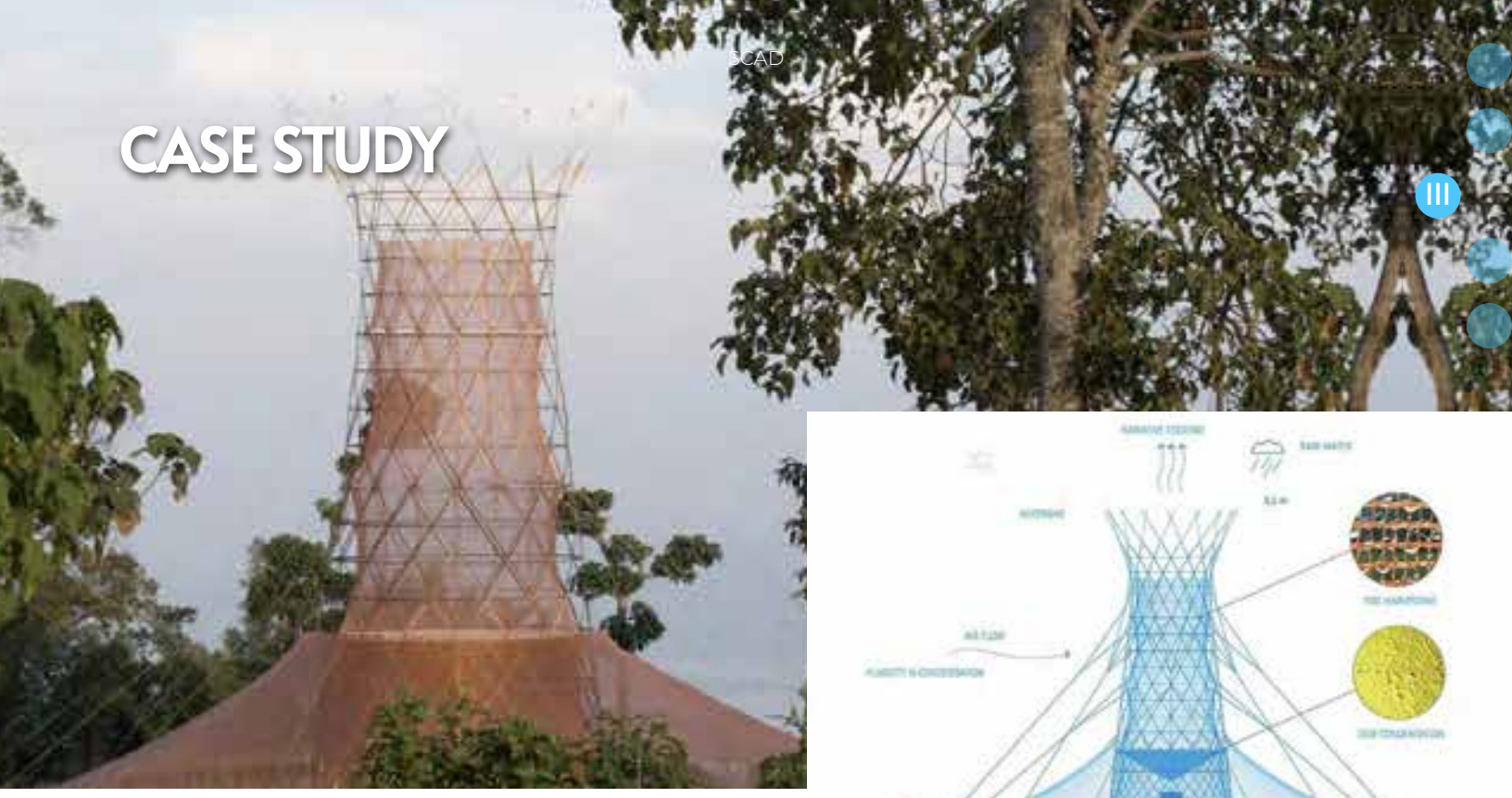
Creating channels alongside the plants to direct the rainwater to them

Creating channels alongside the plants to direct the rainwater to them



Constructing a French drain to hold water next to the plants (a trench filled with gravel)

CASE STUDY



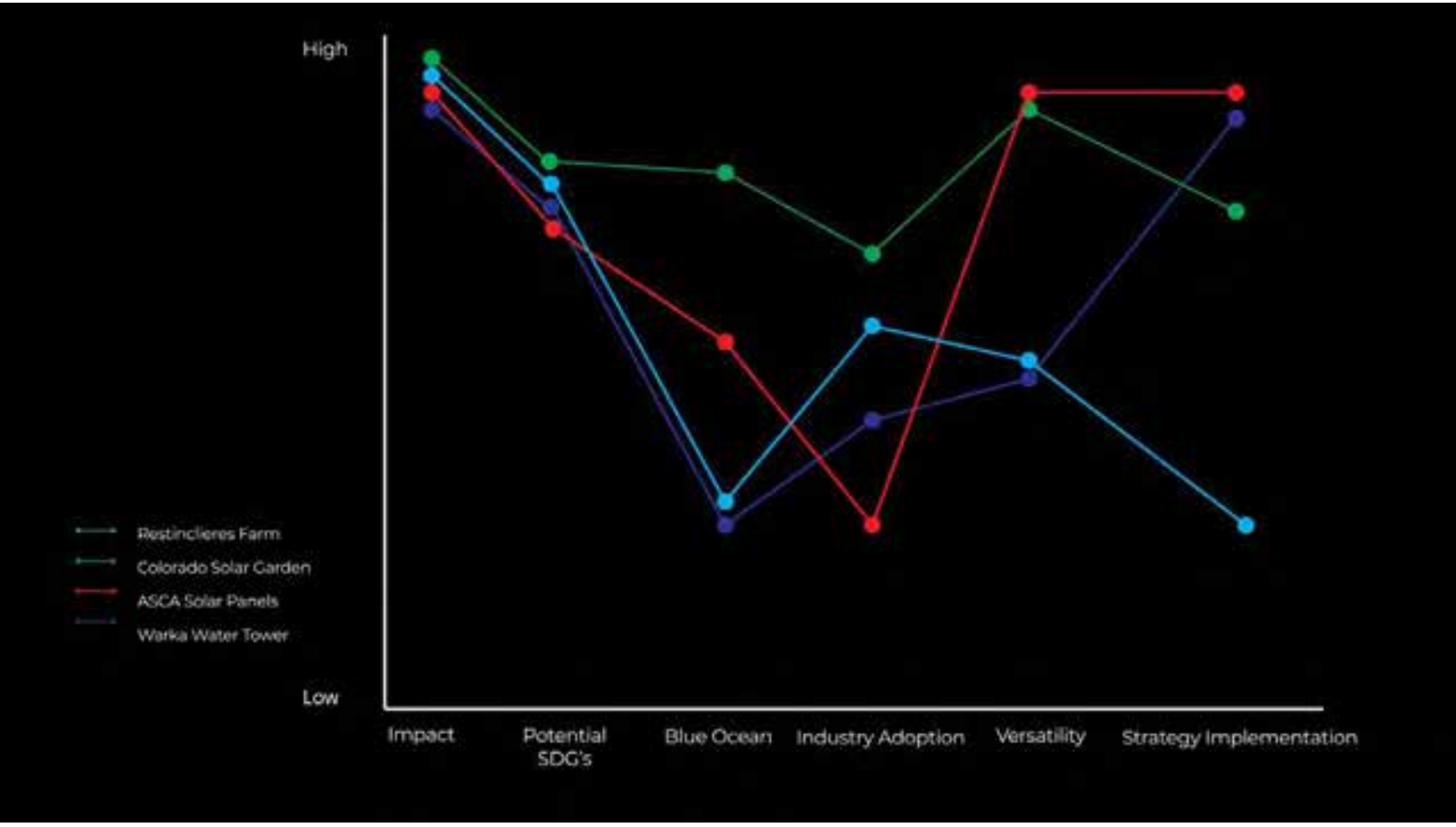
Warka Water Tower

The Warka Water Tower was designed by Arturo Vitori and was constructed by studying his environment and the possibilities of how to collect and harvest water in the most sustainable way. The project was inspired by his visit to a small village called Dorze in Ethiopia, seeing women and children walking extremely long distances every day to bring water home. His aim was to create a structure that would enable the community to extract up to 100 liters of water a day without the reservoir running dry.

Design solution:

The solution created was a tower made of a bamboo frame supporting a mesh polyester interior. Rain, fog and dew can condense against the mesh and trickle down a funnel into a reservoir at the base of the structure. A fabric canopy shades the lower sections of the tower to prevent the collected water from evaporating. This is designed as an open source concept; meaning the local community were trained how to make it and are free to repeat it as much as they like.

Competitors Analysis Chart

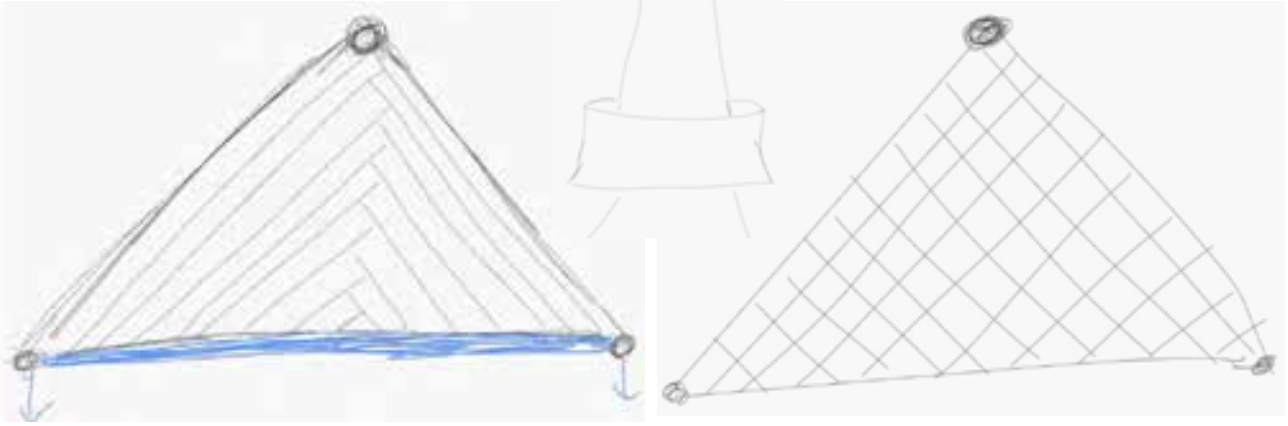


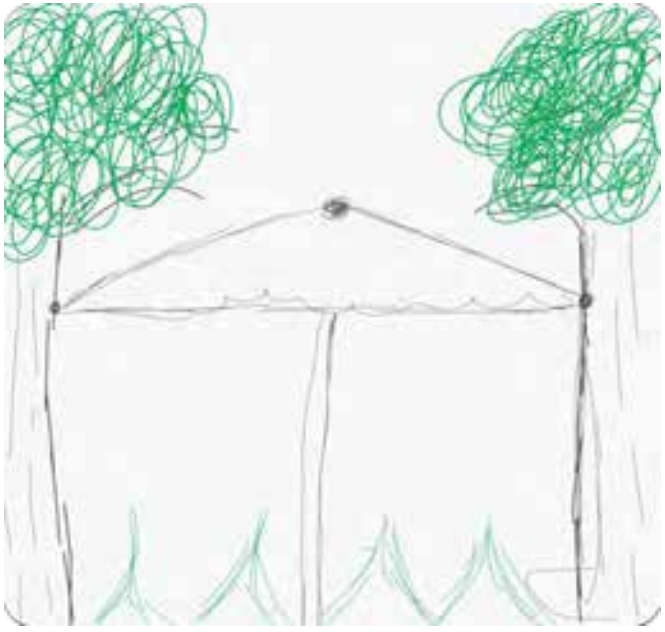
We compared case studies based on several key elements from our Final species selection evaluation matrix including potential sustainable development goals implemented, impact, versatility, and more. The Colorado Solar Garden proved to be a great example of a system in place that could give us the most insight into how the process of using solar energy as a resource in agriculture could succeed.

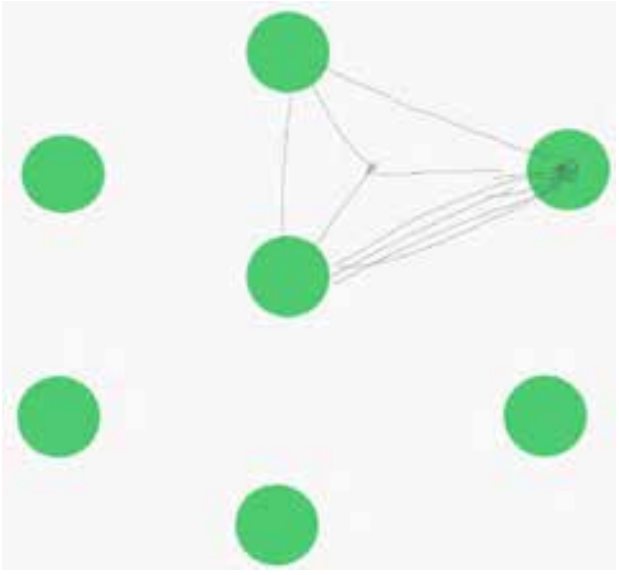
Conceptual Stage I

After gathering much research and a better understanding of agroforestry, agrivoltaics, advantages of flexible solar panels, and rainwater irrigation systems, our team began our initial development-. *To create a design that strengthens the positive impacts on mid-sized farms in the US.*


Solar Energy
UV Protection
Water Dispersion
Nutrient Quality
Resources To Manage
Produce Collection
Manpower Organization
Time Efficiency

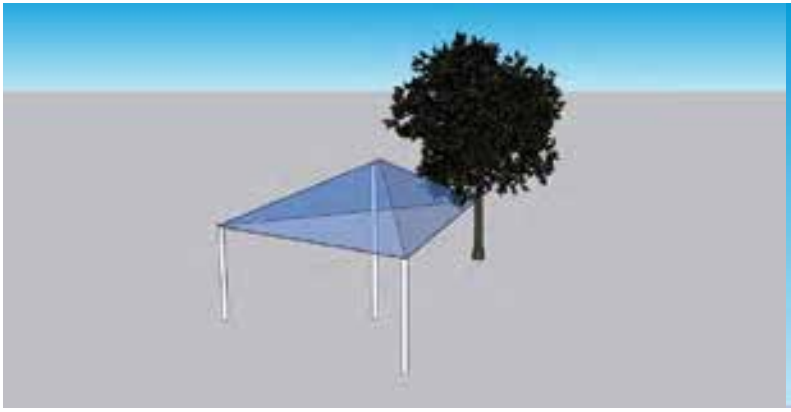


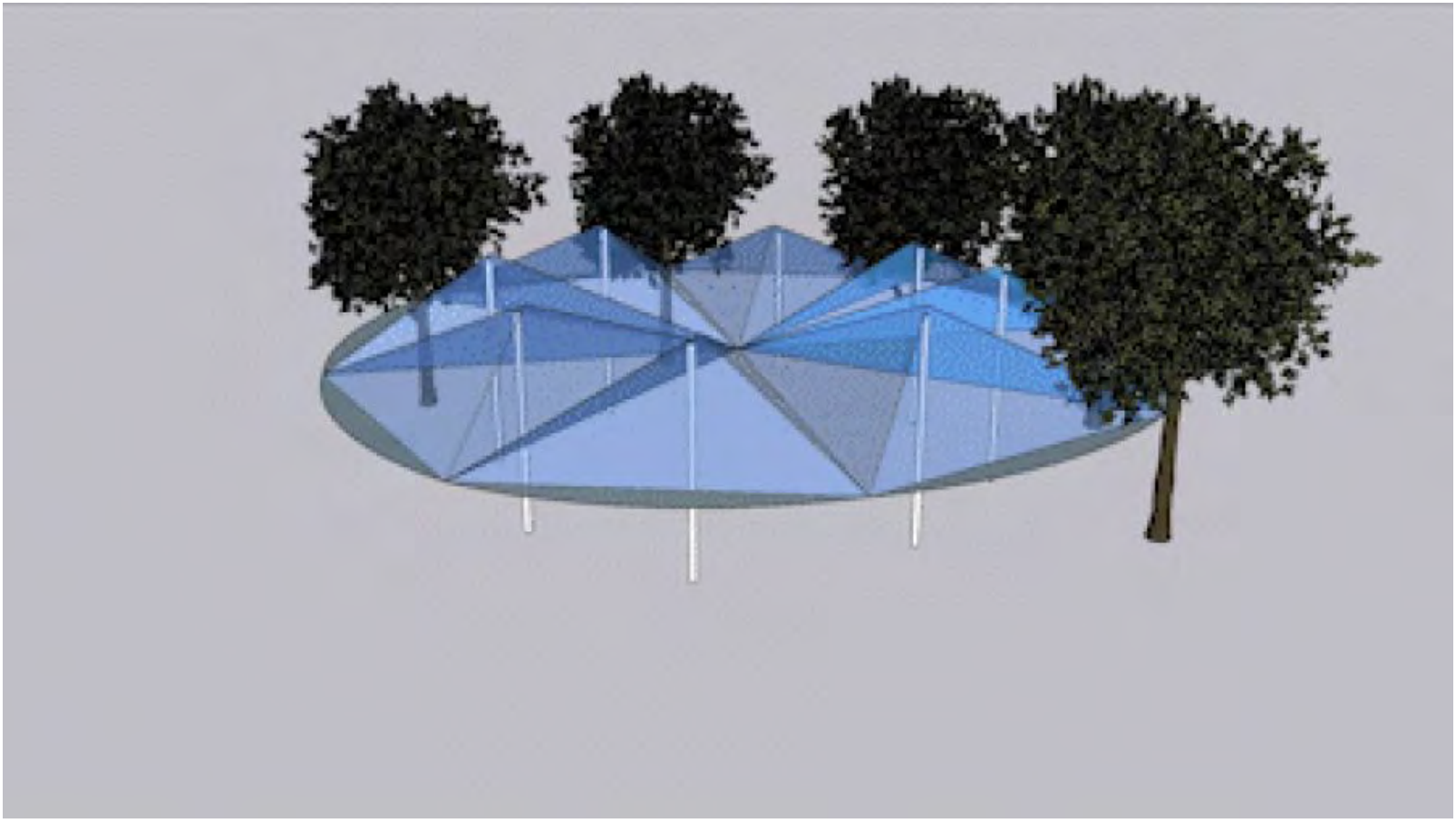




Initial Sketches

Knowing what types of resources we wanted to help manage was only a small piece of the puzzle; how we were going to do so is a completely different story. Beginning with a very simple concept to start, we explored the possibility of developing a series of geodesic panels that would cover the ground below trees, protecting them from UV radiation, wind, predators, excessive weather conditions, and more, all while encouraging the reinstatement of agroforestry practices. For more detailed renders, follow to the next page.





Applied in Context

Who:

Mid-sized farm owners seeking alternative, affordable conservation solutions for new crops

Self-sustaining average users seeking an alternative to greenhouses & garden plots

Agriculture innovators exploring new options

Where:

Beginning with application in the MMD Region, then expanding from there

To hone in our design, we revisited who we were designing for, what it'd need to do, how it would do it, and more. Introducing our new and improved Applied in Context.

Why:

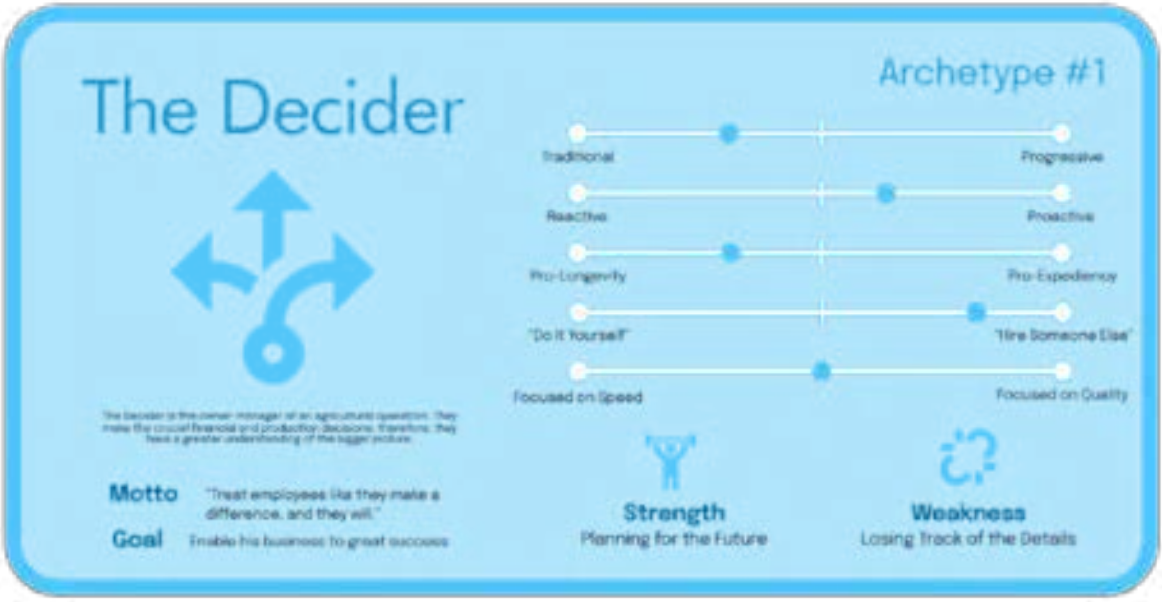
To help people from underprivileged communities grow their own food, create jobs for them and give them the opportunity for a more stable life.

How:

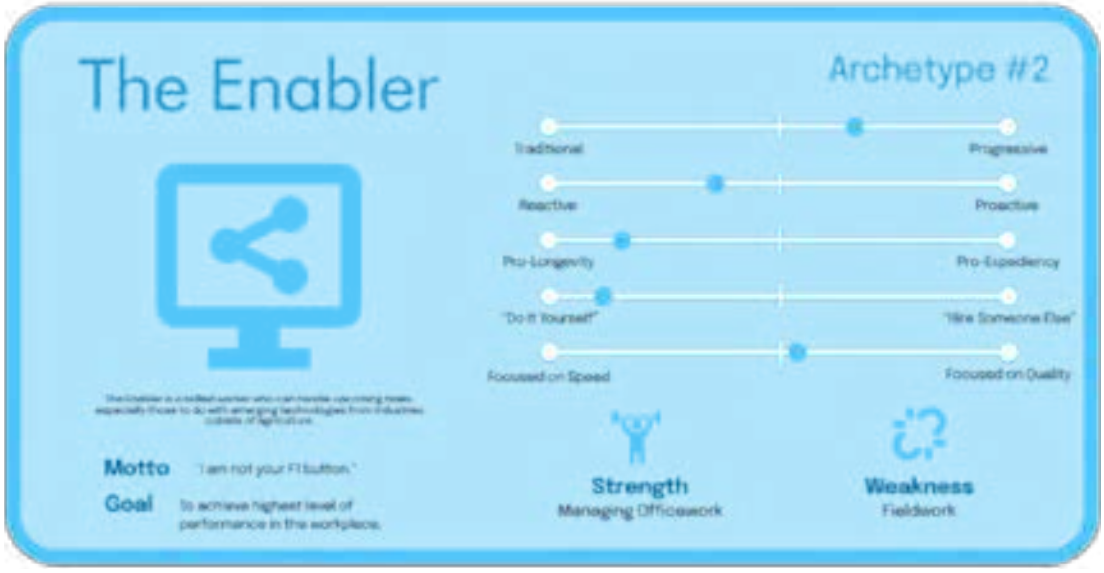
Using structural interference to redirect light for sun protection.

Agricultural Archetypes & Personas

To further develop our understanding of the field we're working in (pun intended), we categorized our archetypes into the types of workers that would be part of an ideal agricultural farming system. We classified them as the Decider, the Enabler, the Specialist, the Doer, and the Advisor. Furthermore, our personas embody these archetypes and represent the ideal candidates who would be interested in agricultural innovation.



The Decider is the owner-manager of an agricultural operation. They make the crucial financial and production decisions, therefore, they have a greater understanding of the bigger picture.



The Enabler is a skilled worker who can handle upcoming tasks, especially those to do with emerging technologies from industries outside of agriculture.

The Specialist has highly refined technical skills in specific agricultural areas from plant science, to livestock management, to regulatory compliance. They also have great interdisciplinary dexterity.

The Doer could be considered today's basic farmhand; although their tasks are seemingly simple, they can perform certain activities with precision that cannot be matched by modern automation.

The Advisor is a highly educated & experienced specialist who offers skills to farm managers; they will only grow in relevance and worth as farming demands greater efficiency and maximization of land, labor, other assets and system

Persona #1

Ben Marlett

Owner of Sundew Farms

Mississippi, USA
59

Biography

Ben is a fifth generation farmer from Mississippi who has been running the farm for forty years. He has three children who no longer live with him, but they are urging him to seek out more conservation practices.

"My farm and my kids are everything to me, and they usually know best, so maybe there's something to this 'conservation' thing."

Goals

- Nutrient managment
- Manage soil erosion
- Increase revenue

Pain Points

- Soil degradation
- Decline in revenue
- Soil Tilling

Agricultural Practices Exposure

Conservation Cultivation Awareness

Environmental Engineering Knowledge

Persona #2

Sara Synder

Manager of OakFarms

New Jersey, USA
31

Biography

Sara is a third generation farmer who is determined to continue her family's legacy, but she wants to be more conscious of sustainable practices for the future of the farm. She is passionate about the place she calls home and is an advocate for local, sustainable farming in her community.

"I'm not going to say my mom gave birth to me in the middle of the corn field, but it sure does feel like that sometimes."

Goals

- Support community's economy
- Preserve agricultural land
- Improve irrigation

Pain Points

- Outdated irrigation system
- Decline in revenue
- Impacts on natural habitats

Agricultural Practices Exposure

Conservation Cultivation Awareness

Environmental Engineering Knowledge

Persona #3

Sam Jeffers

Environmental Engineer

Tennessee, USA

43

Biography

Sam worked as an environmental engineer for over a decade. She has always had a passion for agriculture and has dreamed of running her own farm. Sam recently bought a farm for her and her family to test out new practices.

"I love engineering but it's about time I spend more time with my family and test out new farming practices I've discovered through my old job."

Goals

- Improve quality of land
- Efficiency of farming
- Sustainability of practices

Pain Points

- Innovation
- Effective tools
- Good quality mechanics

Agricultural Practices Exposure

Conservation Cultivation Awareness

Environmental Engineering Knowledge

Persona #4

Will Adams

Student & Farmer

Oklahoma, USA

22

Biography

Will Adams grew up visiting and spending summers on his grandparents farm. Although he loved that lifestyle, he decided to persue an education in the city. After some contemplation, and an invitation from his elderly grandparents, Will decided to move back out to the country and take over running their farm.

"Never in a million years did I think I'd take over the farm, yet here I am! I love this land."

Goals

- Make profits
- Increase crop yelds
- Reach customer needs

Pain Points

- All tools are outdated
- System must be able to grow
- Low maintenece

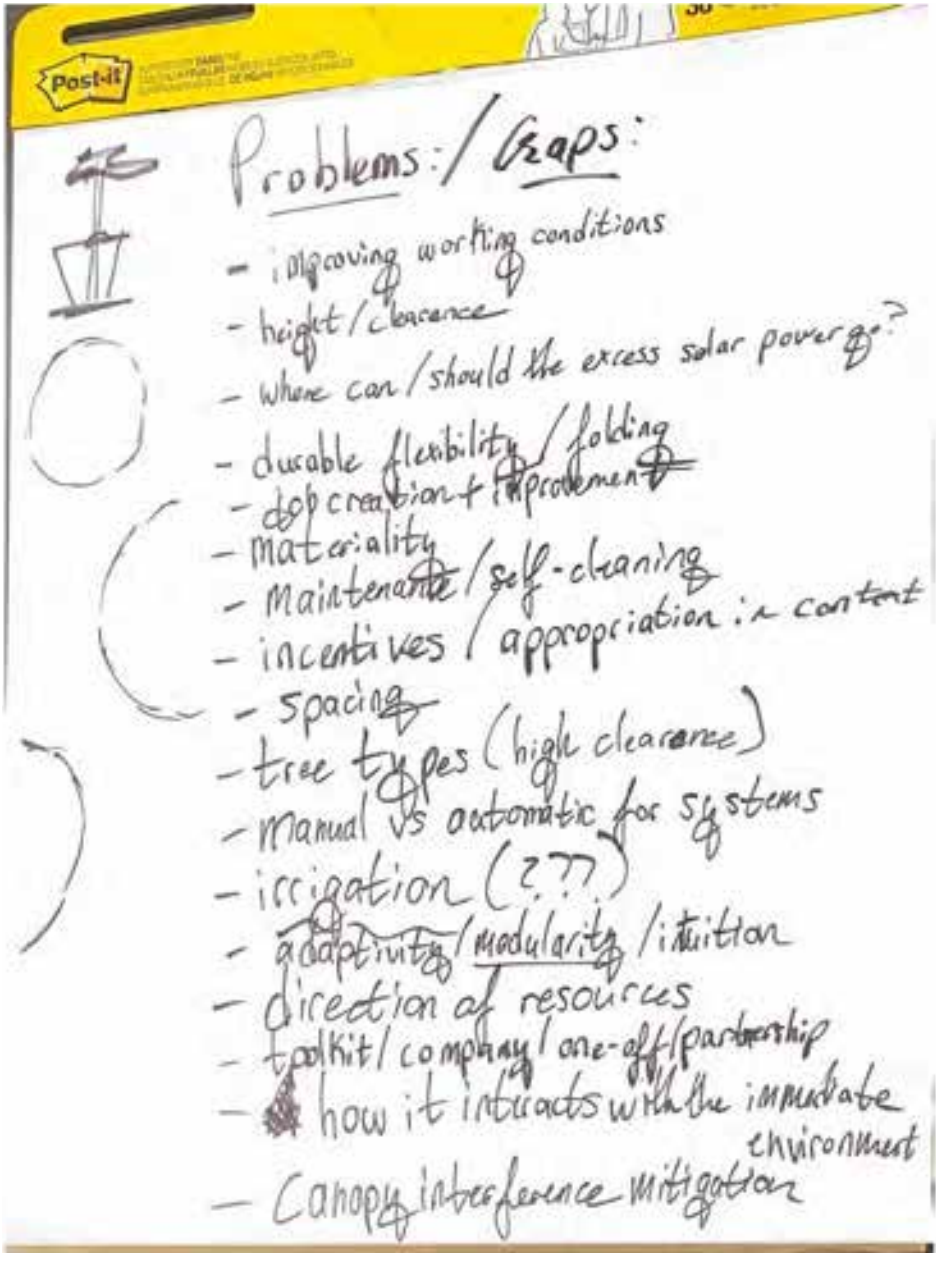
Agricultural Practices Exposure

Conservation Cultivation Awareness

Environmental Engineering Knowledge

GAPS IDENTIFIED

Following a discussion about our users, their needs, and the current state of our design, we quickly identified the gaps in our knowledge. Interestingly enough, this served as an amazing starting point for our primary research, where we would be able to consult with professionals in their respective fields to get their opinion, point of view, and thoughts on all the areas we felt uneasy pursuing as beginners in this space.



PRIMARY RESEARCH

In order to further develop our design we conducted primary research studies, reaching out to a variety of industry professionals to provide us with insights, advice, and potential obstacles we may encounter in the development and implementation of our agricultural resource management system

INTERVIEWEES

Samuel Cote

Sydney C.

Anonymous

Barbara D.

Michael G.

Reid Archer

Scott Lauretti

Interviews

Samuel Cote

Certification Engineer
Plug Power

Environmental Engineering
The Specialist (Archetype)

"Coming from an environmental engineer, this system has a lot of benefits in the long term; I agree, it's one of the best and only things we can do going forward to make a sustainable future."

Summary of Insights

- Monocultures in general are not great; they're very vulnerable to disasters & viruses.
- Diversification won't solve all our supply chain issues, but being able to have more locally grown and diverse sources of food and diversified income for local farmers will strengthen the system going forward.
- The first worry that comes to mind in the diversification of crops is the potential for invasive species.
- Another crop would have to be grown during the other colder half of the year that can both provide crop yield and maintain nutrient density in the soil.
- You definitely need government subsidization to make this a reality.
- The biggest drawbacks of this is that it's labor-intensive, thought-intensive, money-intensive, and time-intensive practice.
- This system has a lot of benefits in the long term; I agree, it's one of the best and only things we can do going forward to make a sustainable future.
- Carbon sequestering technologies are really, really slow-going - it's one of those technologies that has been taking a really long time to pick up.
- To build a more sustainable future, we need to take carbon out of the atmosphere and lock it away permanently.
- Trees are excellent carbon sinks, but they still die; the carbon will inevitably return to the atmosphere; the carbon cycle as a whole is oversaturated at this point and needs to be substantially reduced.
- Integrating this system into an urban or roadway setting would place the carbon sequestering system where it's needed most.
- Materials-wise, go with a metal that doesn't rust easily, is resilient to the elements, doesn't leach into the soil, and is cost-effective.

Interviews

Sydney C.

Mechanical Engineer Co-Op
Joining Technologies, Inc.

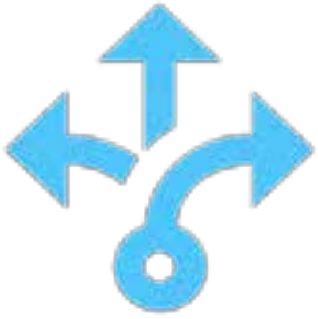
Mechanical Engineering
The Advisor (Archetype)

"You guys design, we make; don't worry too much about the specifics, as long as you have a general idea."

Summary of Insights

- To help the lever system, you'd want the "rope" to wrap around a gear or axis to make it easier to move.
- To lock the mechanism in place after it's been opened, you may want another secondary lever to tighten it.
- You may want to explore potential systems that will slow down the opening sequence, preventing damage.
- With this system, nothing can go through the center, so you'd have to find another solution to how they would all connect.
- To prevent rusting, I'd recommend treating it in advance.
- Keep in mind that certain reclaimed steel has already been treated, which would make it more difficult to work with.
- In your solution, specify the exact type of steel you'd like to use as there are many types.
- Using a standard tube for the center "trunk" could be more cost-effective in the long run since the size would be far more standard.
- Make sure the lever to open the system must be pulled down so workers could use their body weight.
- If the design accidentally causes the lever to be pulled in the opposite direction, you could always add another axis below the lever to reverse it.
- Fiberglass may work, but the potential to recycle and repair will be reduced; also, it would be more custom and expensive

Interviews



Anonymous

Manager/Owner
Agrivoltaic Farm

Farmer Owner
The Decider (Archetype)

"Agroforestry and agrovoltaics both provide shade to crops, but the added benefit of using both is that farms can definitely generate more money for their business."

Summary of Insights

- When implementing, farms need permission from utility, government, and the finances to support it.
- In an agrivoltaic system, solar arrays installed first because if the land was prepped before hand, the soil would be too soft to work on.
- This system has the potential to strengthen community involvement; allowing for the students, school districts and families in the community to collaborate, conduct research, and attend events here.
- Farmers haven't already implemented solar in agriculture because their not educated on the possibilities, they lack proper finances, or they do not want to loose the time it takes to implement.
- They gained general knowledge about this system through Universities in their community that were conducting research on agrivoltaic systems. From this, they were introduced to farms in European countries that already successfully implemented this system.

Interviews

Barbara D.

Community Agroforester
Savanna Institute

Agroforestry
The Advisor (Archetype)

"One of the main goals within the agroforestry world is creating a community and spreading education, resources, and knowledge on the subject"

Summary of Insights

- Environmental benefits end up being economical benefits
- Agroforestry requires a lot of effort at the beginning, but low maintenance afterwards
- There is no set implementation process
- Agroforestry is seen as a 3D layer system of agriculture
- Look at impact on people, planet, profit, and social

Interviews

Michael G.

Associate Director, The Center for Agroforestry
University of Missouri

Agroforestry
The Advisor (Archetype)

"Farmers can't really start an agroforestry farm on their own, it requires lots of consultation and planning from multiple people in different disciplines, all working together."

Summary of Insights

- Think of end product for crops
- Step 1 is assessing the farmers goals and values
- See what crops and trees thrive in that specific subregion
- Agroforestry allows for multiple sources of income for farmers
- specialty crops have higher value, which allows for a larger profit margin for farmer

Interviews

Reid Archer

Co-founder of Savannah Victory Gardens
Savannah Victory Gardens

Urban Gardening
The Specialist (Archetype)

Crafting ecological and abundant spaces for coastal Georgia.

Summary of Insights

- Drip irrigation can conserve upwards of 40% of usual water use
- Can save money and establish a lasting irrigation system
- Low maintenance and superior function
- Make sure a system is in place to control water flow to avoid over or under watering the plants

Interviews

Scott Lauretti

Fam Owner, G&S EC Farms,
Claxton, Georgia

Farm Owner
The Advisor (Archetype)

"Whatever I produce want it to be as healthy as possible for whoever is going to consume it"

Summary of Insights

- 2 people working there only (himself and one other care taker)
- sustainable practice: Intentionally Minimize use of chemicals almost none.
- He has noticed there are more people like him, people who have done other stuff and are now going into boutique farming
- Waste: none of it,re-uses almost all waste as much as possible
- Weeds and invasive growth is the absolute enemy of cultivation, might be challenge for agrofarmers cuz the more stuff competing harder it is for drive.
- Putting new technology in place has been done before just takes time
- Evolutionary concepts in farming: drone technology, digital controlling technology that can assess what's happening in farms now that didn't exist before.

Affinitization

Following our primary research, we engaged in affinitization, a process many in the design world have a love-hate relationship with. Beginning with the raw data collected from our interviews, we slowly but surely honed in the shared ideas and concepts, resulting in an amazing set of insights that drove our final solution.

Final Primary Research Insights

Innovative and complex agriculture systems benefit farmers and their business, allowing for higher yield and other environmental benefits.

Any business needs outside support, views, perspectives, and ideas, and farms are no different; with the correct resources, they can thrive.

Complicated technology isn't out of reach within natural settings; by approaching it from a logical and structured point of view, they can be incredibly impactful.

By using Agroforestry with proper assessment and education, a farm's revenue could increase exponentially due to multiple income streams while also helping the environment.

PHASE 3

THE FINAL SPROUT

IV

Introducing OASYS, the Omni-Agricultural System. It takes inspiration from the extensive resource management capabilities seen in our selected species, the Begonia pavonina, to heal our relationship with the Earth's existing systems. This design acts as a bridge between the artificial and natural, allowing us the opportunity to grow it back, right down to the roots.

text

SCAD

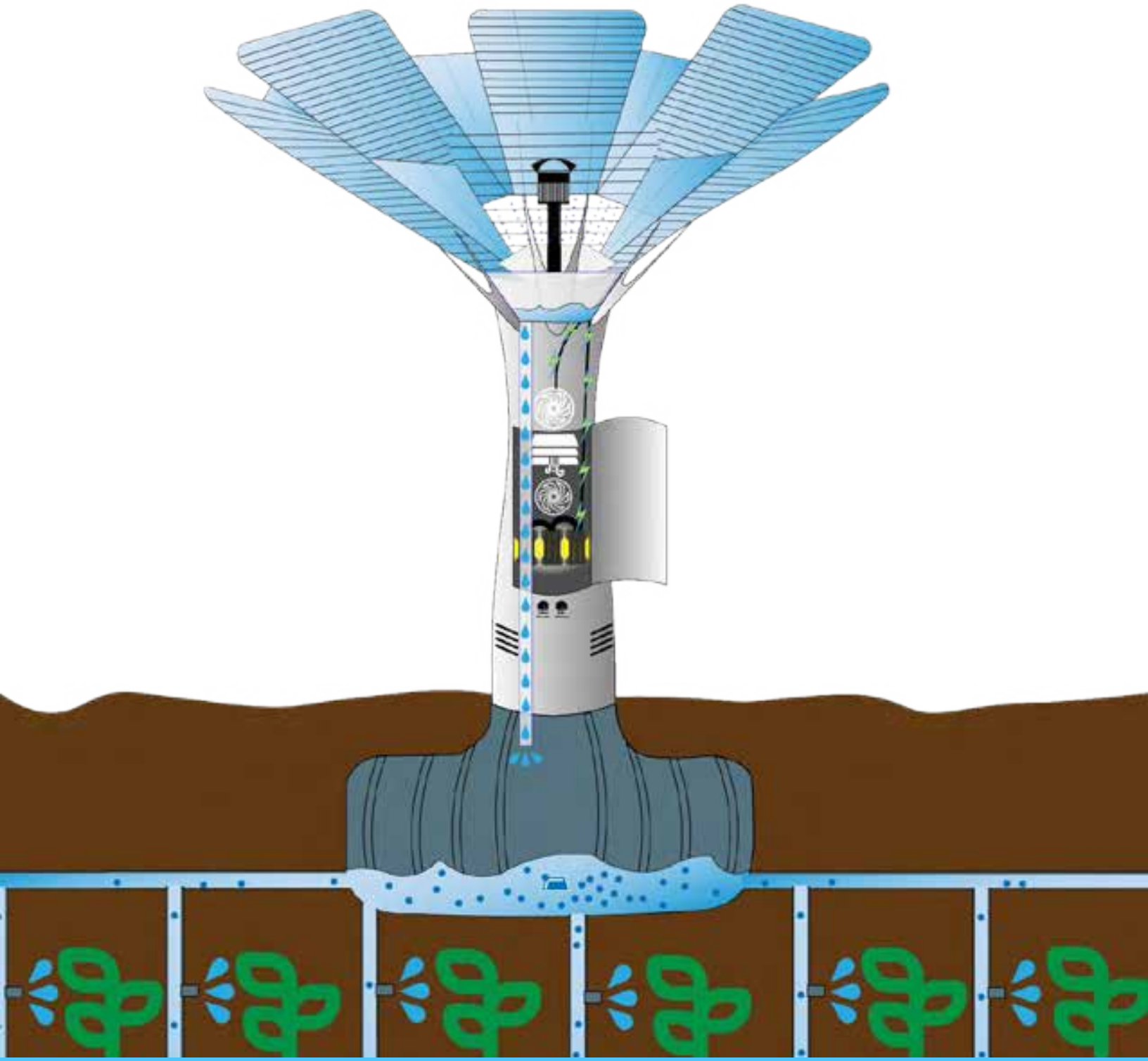
How did we get from the *Begonia pavonina* to our final design, OASYS?

Taking on the challenge of agricultural supply chain insecurity and soil health seemed like an impossible situation to overcome due to all the moving parts. Completely re-innovating an agriculture system by using a method that has existed for thousands of years is may be completely insane, so, that's why we looked to nature's own impossible situations to see what types of species overcame their environment to survive.

On the exact other side of the world, the dark undergrowth of the Malaysian tropical rainforest houses our favorite plant, the Begonia pavonina, whose iridescent leaves use a special type of chloroplast and quantum physics to slow down light and increase efficiency in an environment completely lacking solar energy. It's a fascinating little system, using structural interference to redirect resources for a whole host of functions, adapting to survive in impossible conditions caused by the very nature of its own home.

We may not have the thousands of years it took nature to create the hearty *Begonia pavonina*, but we have taken inspiration and designed OASYS to mirror the Begonia's efficient resource management system. Within OASYS, you'll find that the solar energy capturing system mimics the Begonia's approach to solar energy; the *Begonia pavonina* houses two types of leaves, one to gather energy in low light conditions and the other to gather light in normal conditions. Similarly, OASYS can redirect solar energy to multiple locations in its own system. Not only that, but OASYS' irrigation system efficiently gathers and redirects water to efficient usage in the exact same way the Begonia's leaves guide water to the forest floor to prevent oversaturation within the warm Malaysian climate.

Although OASYS may not look like the Begonia in its most raw form, the system as a whole is essentially the result of a lovechild created by the *Begonia pavonina* and five passionate biomimics. Here, we've developed a system that could potentially reverse the damage we've caused and strengthen the Earth beneath our feet for years to come, all inspired by the earth itself.



OASYS

Goals:

1. Contribute to rapid, innovative atmospheric decarbonization
2. Revitalize soil health & increase crop yield
3. Give energy agency back to mid-sized farms

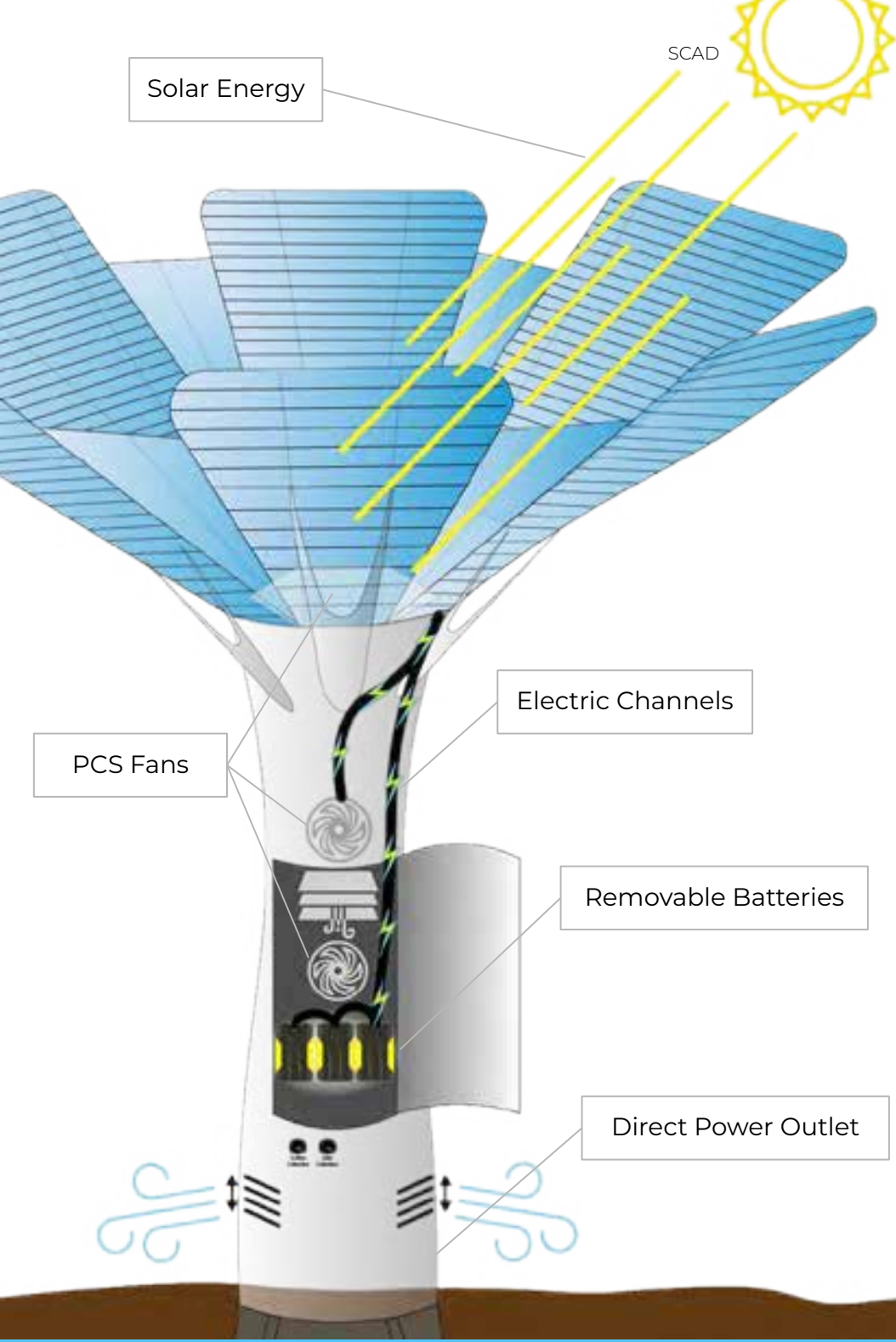
Although we may be a bit biased, we're proud to say that OASYS is an unprecedentedly amazing piece of technology. By using existing resources, the system is free-standing and provides the majority of what crops need to thrive, allowing farmers to have more control over their yield while taking care of their land, not abusing it.

Through our research, we've discovered that many farmers drain their land dry of resources through monocultural, linear farming, which includes over-tilling, nutrient destruction, over-chemical fertilization, and other damaging tendencies. With OASYS, we're encouraging regenerative farming techniques for specifically hand-picked crops, especially agroforestry. Rather than fully replacing the function of a tree, OASYS works in tandem with agroforestry techniques; when an OASYS is planted, saplings are planted on the other flanking side of the crops. Because trees take a certain amount of time to grow, the OASYS system provides many of the benefits one could expect to have from agroforestry, but without having to wait for the trees to grow. How so, you may ask?

OASYS is, in essence, an adaptable, artificial tree with the sole purpose of protecting the crops in its care. Through a series of sensors and monitors, the system automatically adapts. Too hot? OASYS' leaves fold down to protect the crops below from harmful UV rays. Too much wind? OASYS' leaves can fold back up to prevent damage to the system. Too dry? OASYS can release additional water into the soil through an underground piping system. That isn't where the system stops, though; OASYS houses a set of flexible solar panels that gather solar energy and power a miniature partial carbon sequestering system, pulling carbon down from the atmosphere, sending it through a filter, and releasing clean air. This captured carbon is then processed off-site into a carbon cartridge, allowing it to be injected back into the soil with our integrated irrigation system. This process enables surrounding plants to benefit from nutrient rich soil and increase their yield a massive amount. For more information about the specific resource management abilities of the system, continue on the next page.

Solar Energy Collection

Gathering renewable, reliable energy is a must-have on most farmland. The amount of opportunity and open fields make their crops the perfect location for solar panels, but in most cases, solar panels take up too much space and damage the crops' overall yield. With that being said, those are for regular, non-permeable solar panels. We think we have something a bit different.



Rather than using large, inefficient solar panels in our design, we've elected to use flexible, translucent solar panels created by ASCA to line OASYS' leaves. These panels are marvels of engineering: lightweight, efficient, and cost-effective. This company is well-known for their ability to adapt their design to the needs of every specific project, but we've been able to cross-reference much of their previous work to calculate the possible energy collection from this system.

If we utilize 12.81 m^2 as we have in our model when opened, it's possible to collect 4.422 kwh yearly per unit, a fair amount for translucent panels, and more than enough to perform the functions we have tasked for the system. As soon as the ASCA leaves collect the solar energy, it's sent into the trunk of the system and redirected for one of three purposes (next page).

Powering the Internal Partial Carbon Sequestering System

- Specifically the three fans in use

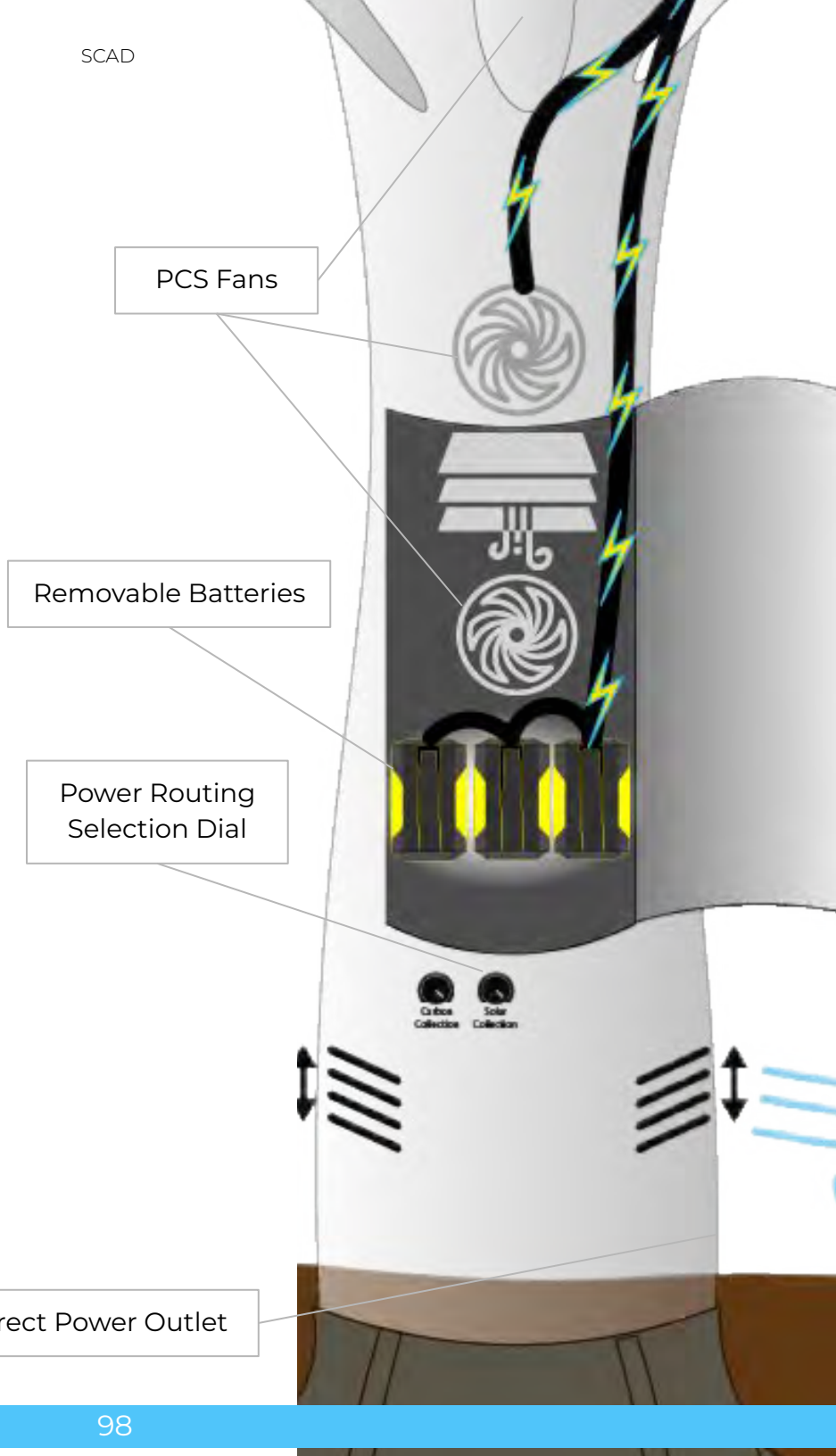
Charging Removable Batteries

- For farming & landscaping equipment
- Power storage for long-term use / reduced solar energy exposure

Direct Power Outlet

- Classic power usage in nearby buildings
- Charging larger agricultural equipment with electric engines, such as tractors

We elected to include an “AUTO” option, which allows the user to employ a more hands-off approach and allow the system to delegate where and when power is used. For example, it would elect to charge the batteries for a set amount of time, but once the batteries are full, it would begin running the carbon sequestering system to ensure no power is lost or used inefficiently.

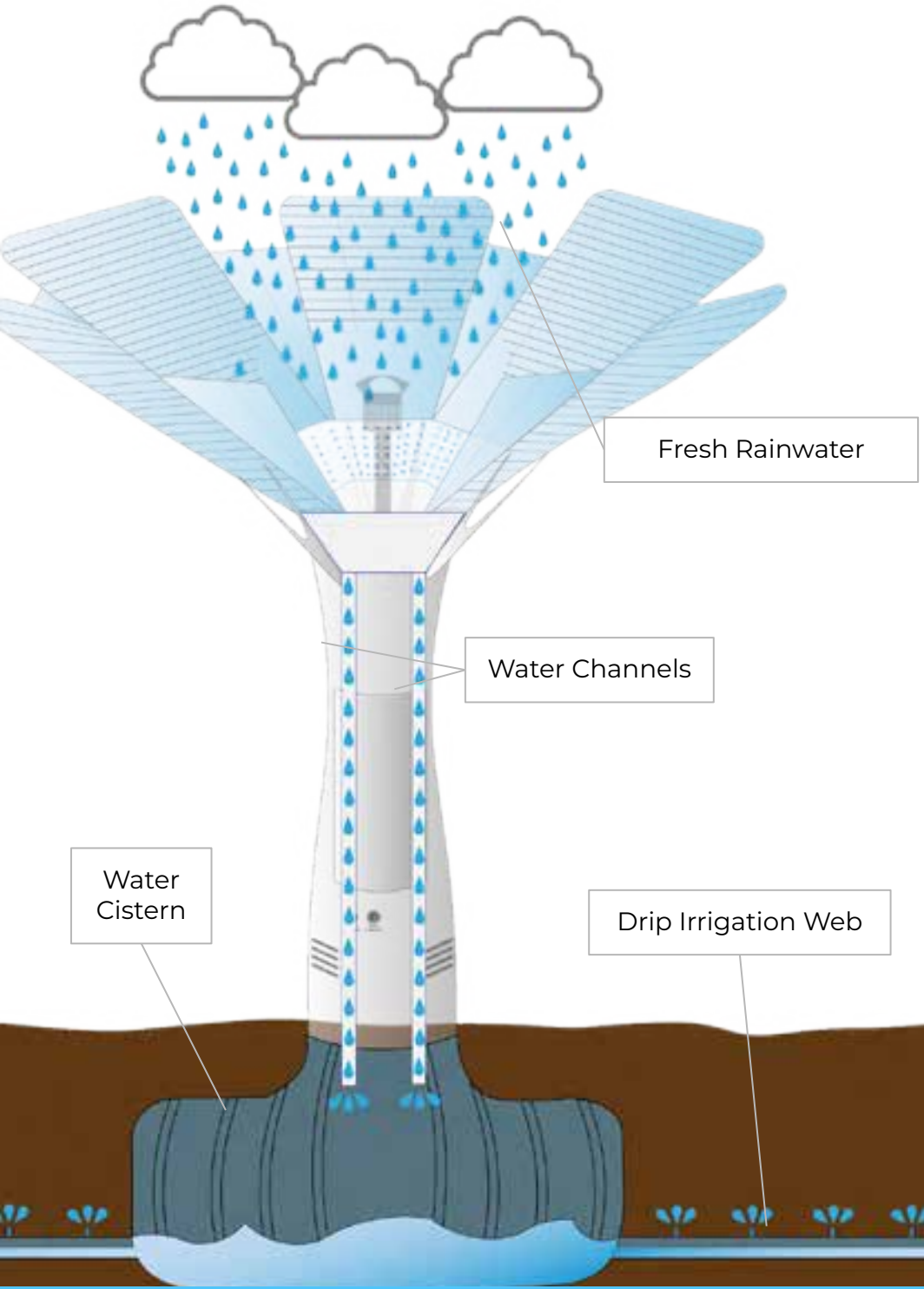


IV

Guiding Funnel
Shape for Collection

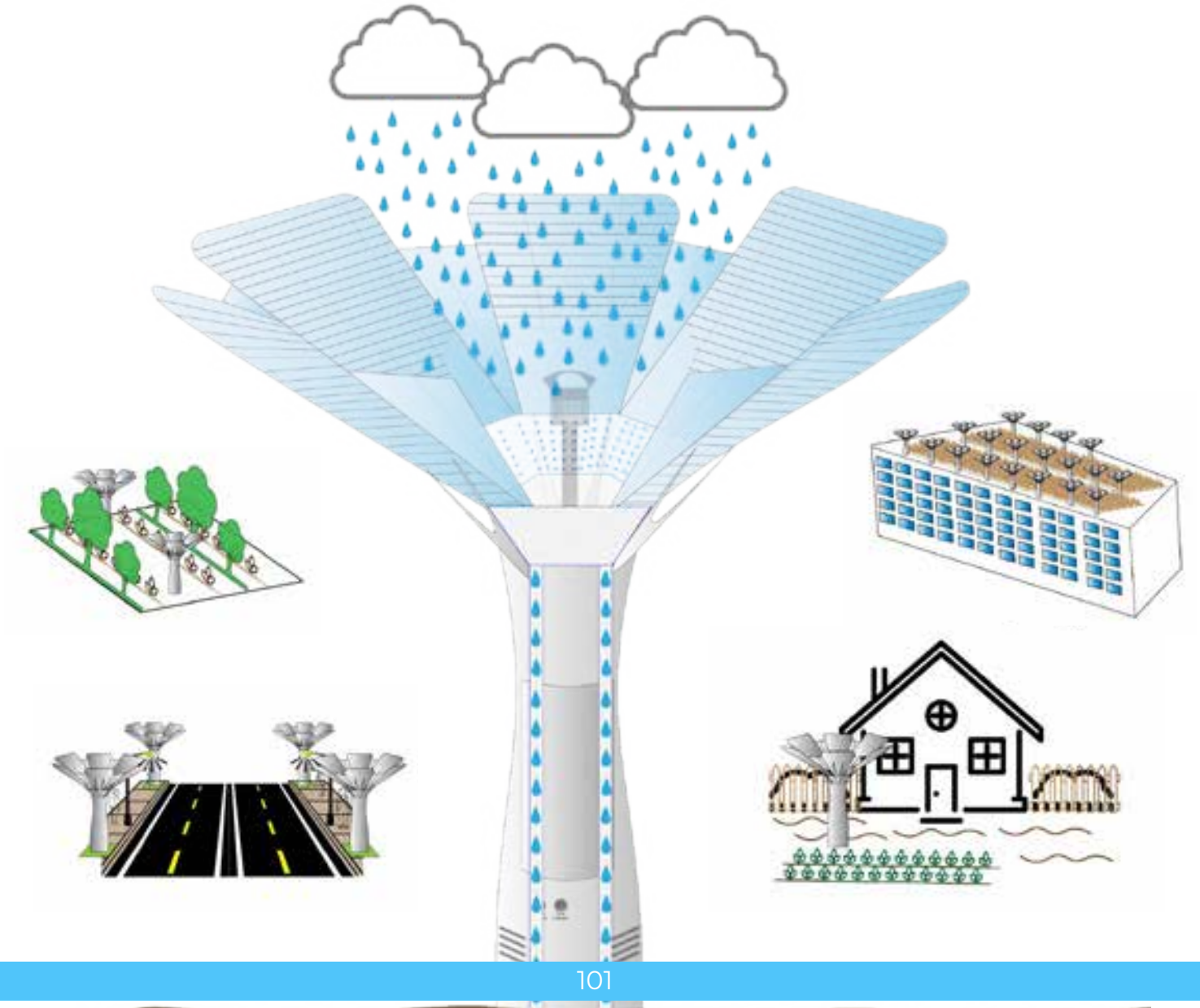
Rainwater Collection & Irrigation

With water dispersion inconsistencies as a large issue in arid farmlands, making sure water coverage is even and thorough is a must. Enter: the OASYS irrigation system.



Beginning at the top of the system, the OASYS' leaf design acts as a pseudo-funnel, guiding rain water into its trunk through a set of simple tubes and then underground to the foundational cistern. This large tank is made out of reclaimed steel (similar to the rest of the system) and connects to a larger web of pipes. The setup is fairly simple, but it takes advantage of a subsurface drip irrigation concept, allowing for slow but consistent water to be dispersed to surrounding crops when needed based on the input collected by a simple moisture sensor.

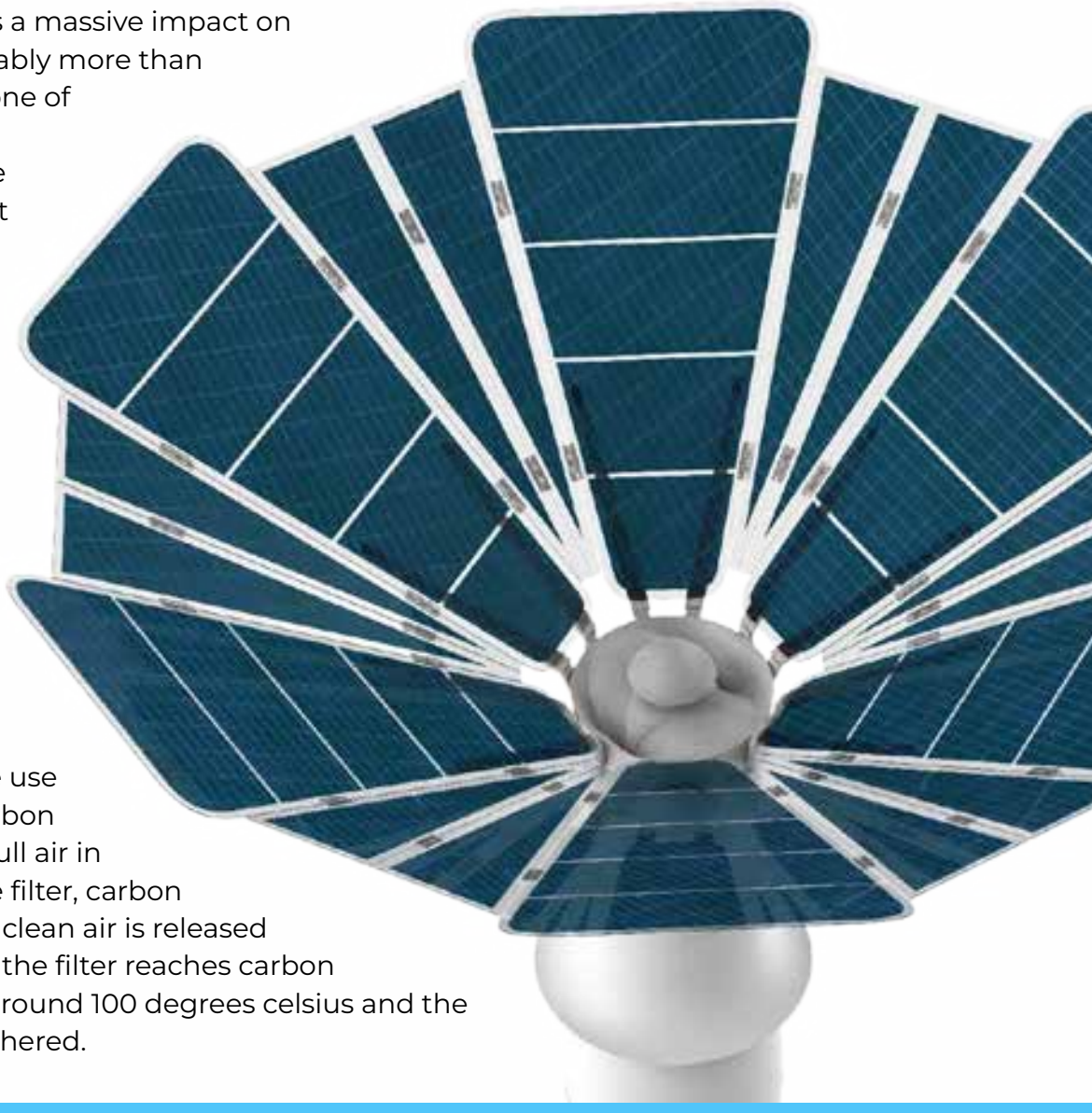
This irrigation system is fairly basic, but that's precisely the beauty of it. Because OASYS is overall incredibly modular, we've designed it so that if a farm manager decided to use their existing irrigation system and simply hook up OASYS to that, they are more than welcome to do so. Making the irrigation system entirely optional also allows the overarching system to be able to be used in more contexts and applications, especially in areas known to not have a lot of subterranean clearance, such as cityscapes and buildings.



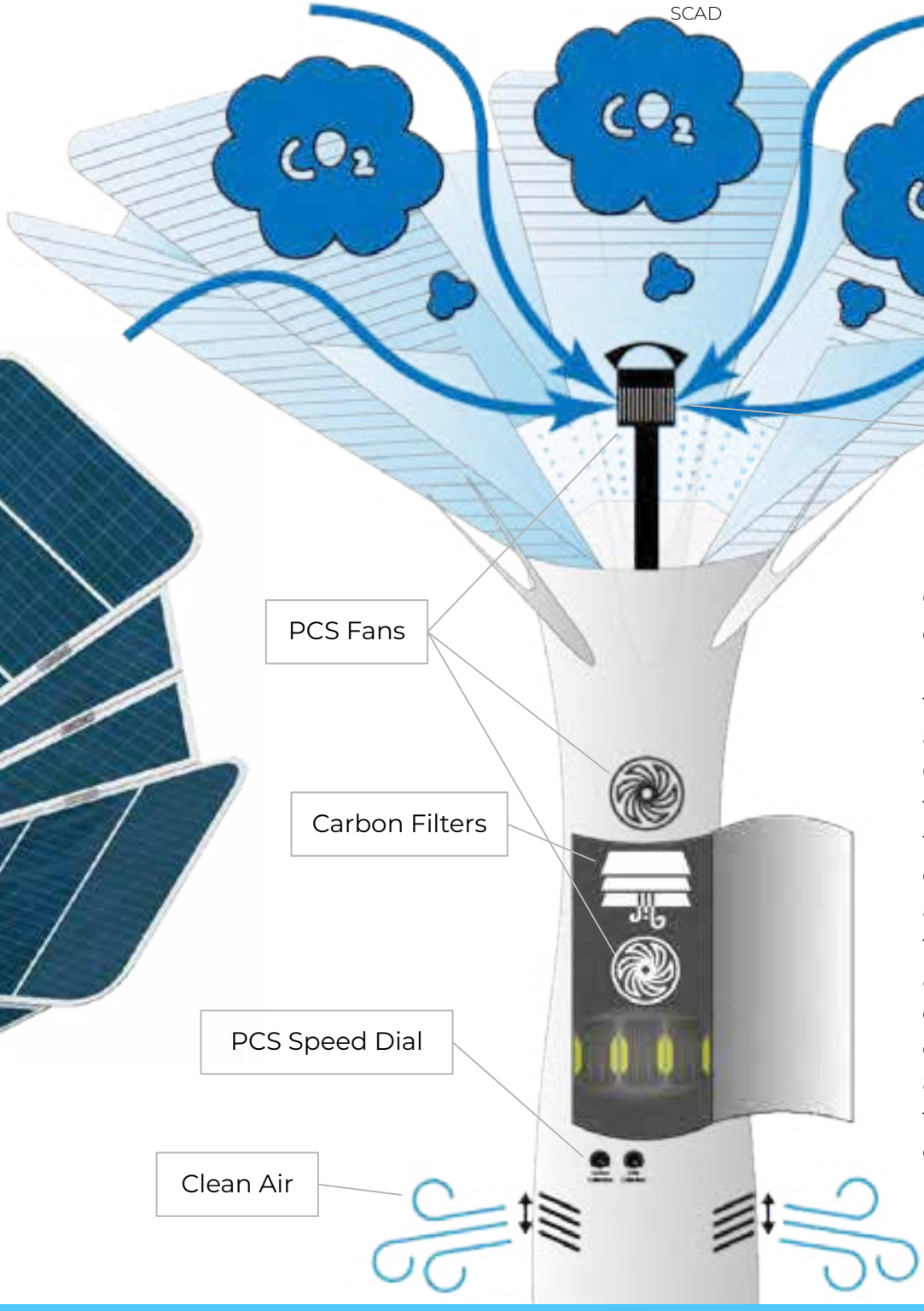
Partial Carbon Sequestration System

Last but certainly not least, the partial carbon sequestering system is likely the crown jewel of OASYS. Our goal with this project was to not only repair the Earth's farmable lands, but also ensure the damage will not happen again in the future. This is, of course, achieved through the widespread application of regenerative farming methods, but that doesn't mean that nature will completely cooperate through that alone.

Climate change has has a massive impact on farming methods, probably more than we care to realize, and one of the main purposes of regenerative agriculture is to take the carbon out of the air and lock it away. So, that's exactly what OASYS does.



Carbon sequestration is fairly complicated, but at its core, the process involves taking carbon from the air, bringing it together, and using it for another purpose. One of our favorite ways of doing this that we researched involved the use of a chemical-based carbon filter. By using fans to pull air in and push it through the filter, carbon would be collected and clean air is released on the other side. Once the filter reaches carbon capacity, it's heated to around 100 degrees celsius and the powdered carbon is gathered.



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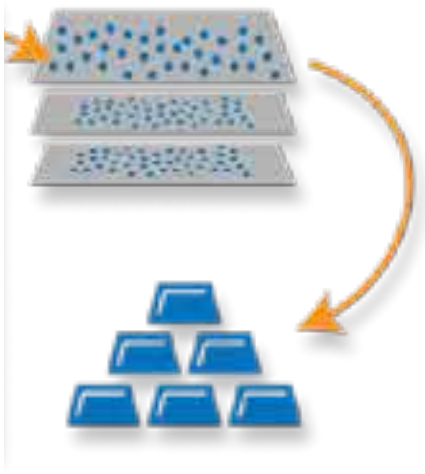
It's incredibly simple, and most of all, incredibly plausible. We've elected to utilize a partial version of this system in OASYS, placing a veritable "stoma" in the center of its leaves that draws air into the trunk. There, three filters collect carbon in succession and a third fan pulls the now clean air down and out, completely free of carbon. The use of three, quiet fans is very subtle and limited in terms of energy output. Depending on each OASYS user's power usage preference, they even have the option to choose whether they'd like to use the partial carbon sequestration system on "Low," "Medium," and "High," each increasing the capture of carbon and need to replace the filters incrementally. In this case, we estimate that having the filters in the system while on "High" would result in them having to be replaced every week, while on "Medium" it would be every two weeks, and so on.



This may seem like a small change, but the impact it could have is massive. Remember when we mentioned that the carbon has to be heated to 100 degrees celsius to be collected? Well, we can't exactly do that in OASYS itself (believe us, we tried), so we've created a neat little collection system instead. As soon as the filters have been fully saturated, they're able to be completely removed and collected by OASYS engineers and brought to an OASYS facility where the carbon is heated, scraped, and collected for a multitude of uses (next page):

Agricultural Application

Carbon Nutrient Cartridges

Here, we've created something we like to call Carbon Nutrient Cartridges, rendered carbon obtained from the filters that is solidified into a porous cartridge, designed to slowly disintegrate over time. Do you remember those food tablets you'd give your fish when you left on vacation? The way they would slowly dissolve and feed your fish, even though you were gone for weeks? Yeah, think that, but carbon-y.

This cartridge can be deployed into the system by popping it into a slide that leads to the irrigation cistern. Over the course of a few weeks, the carbon slowly dissolves and provides an amazing boost of nutrients for the plants in its care. Depending on the request of the OASYS user, this cartridge could even be spliced with optional additional fertilizers to increase plant health, including but not limited to:

- bone meal
- alfalfa meal
- cottonseed meal
- rock phosphate
- blood meal
- feather meal
- greensand
- liquid kelp
- fish emulsion
- fish hydrolysate

"Why is this necessary though," you may ask. Well, just like we mentioned earlier, most fertilizers being used for crop care simple aren't natural and are actually very destructive to the environment. They're littered with an excessive amount of chemicals that damage the very earth they're trying to help. This carbon cartridge provides a natural alternative by getting to the root of the issue (quite literally).

Additionally, research has shown that as plants have adapted to the increased planetary temperature as a result of climate change, they've actually begun using more carbon for growth, meaning that the underground reserves of carbon are being depleted more and more quickly, resulting in less healthy plants at no fault of the farmer themselves. OASYS allows them to inject that carbon right back into the soil where their crops need it most, allowing them to grow faster, healthier, and have a far better yield.

Additional Industrial Applications

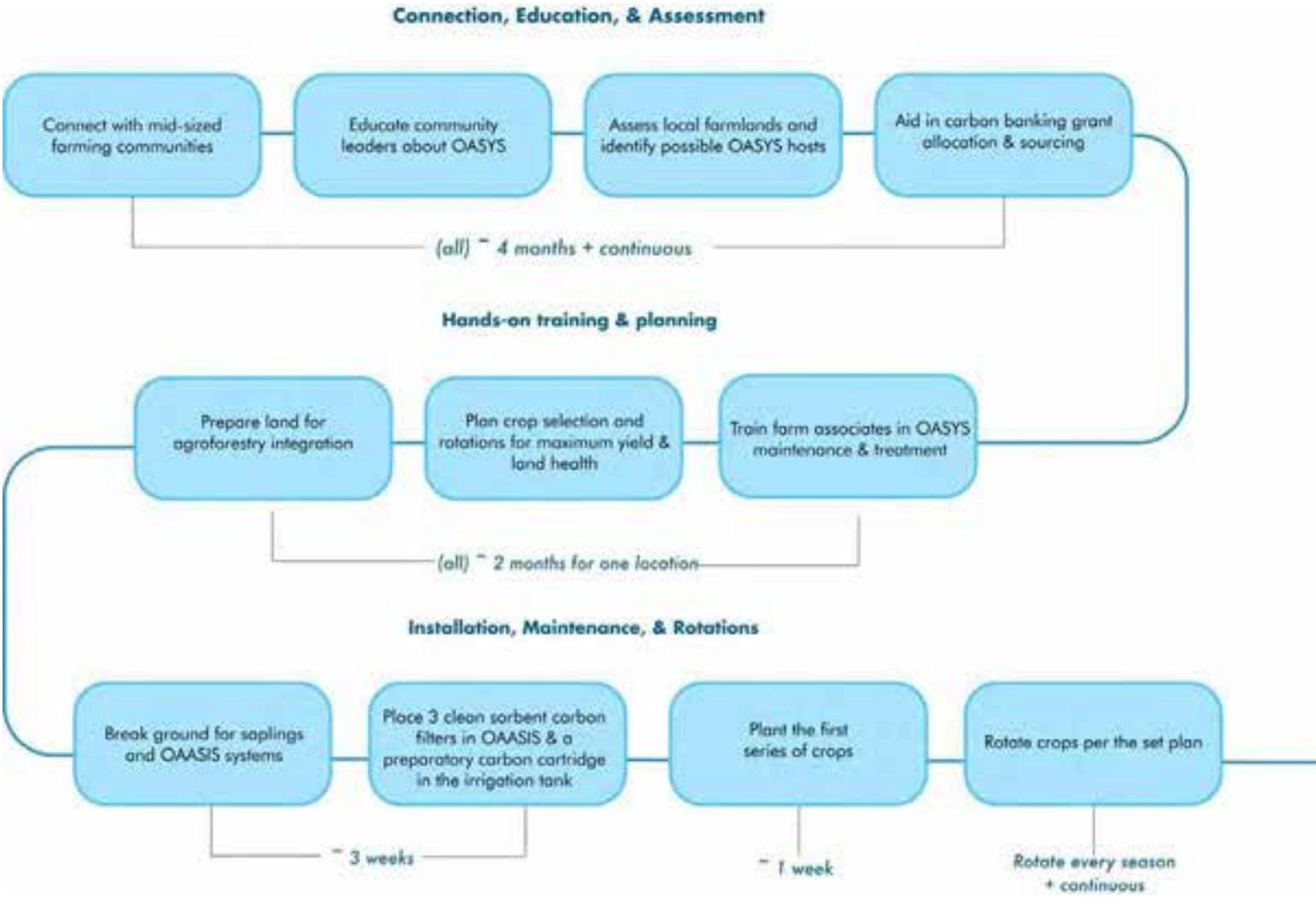
Carbon Bricks

Carbon Bricks are a neutral refractory material, used for high-temperature situations where other materials may crack under pressure. They're manufactured with carbonaceous raw material and an added suitable binding agent, making them true, pure carbon bricks. They have a number of great applications, the most popular of which being blast furnaces to build the bottom and hearth; because it has great thermal shock resistance and a low thermal coefficient of expansion, they make for an amazing alternative to other materials.

Carbon Black Powder

Another use for the carbon is Carbon Black Powder, a raw material with a great number of uses in high-tech applications. It can be used in the electronics, printing or construction industries as a strengthening agent for rubber, pigment, UV stabilizer, and as a conductive or insulating agent. Because of its high degree of porosity, it's high adaptable to many situations and is considered "black gold," as far as materials go within the tech and construction world.

User Journey Map & Timeline



Installation, Maintenance, & Rotations

Place a carbon cartridge in the irrigation tank

~ Recommended 1 every 2 weeks + continuous

Replace 3 clean sorbent carbon filters in OASYS & a carbon cartridge in the irrigation tank

~ Once every 1, 2, or 3 weeks depending on fan speed (high, medium, & low respectively) + continuous

Monitor tree growth annually; as soon as they reach maturity (3-4 years), uproot the OASYS system, relocate it, and plant new saplings in their place

~ 3-4 Years + continuous

IV

Communication, Ambassadorship, & Expansion

Communicate with OASYS users regularly to collect data & monitor progress

~ 2 week check-ins + continuous

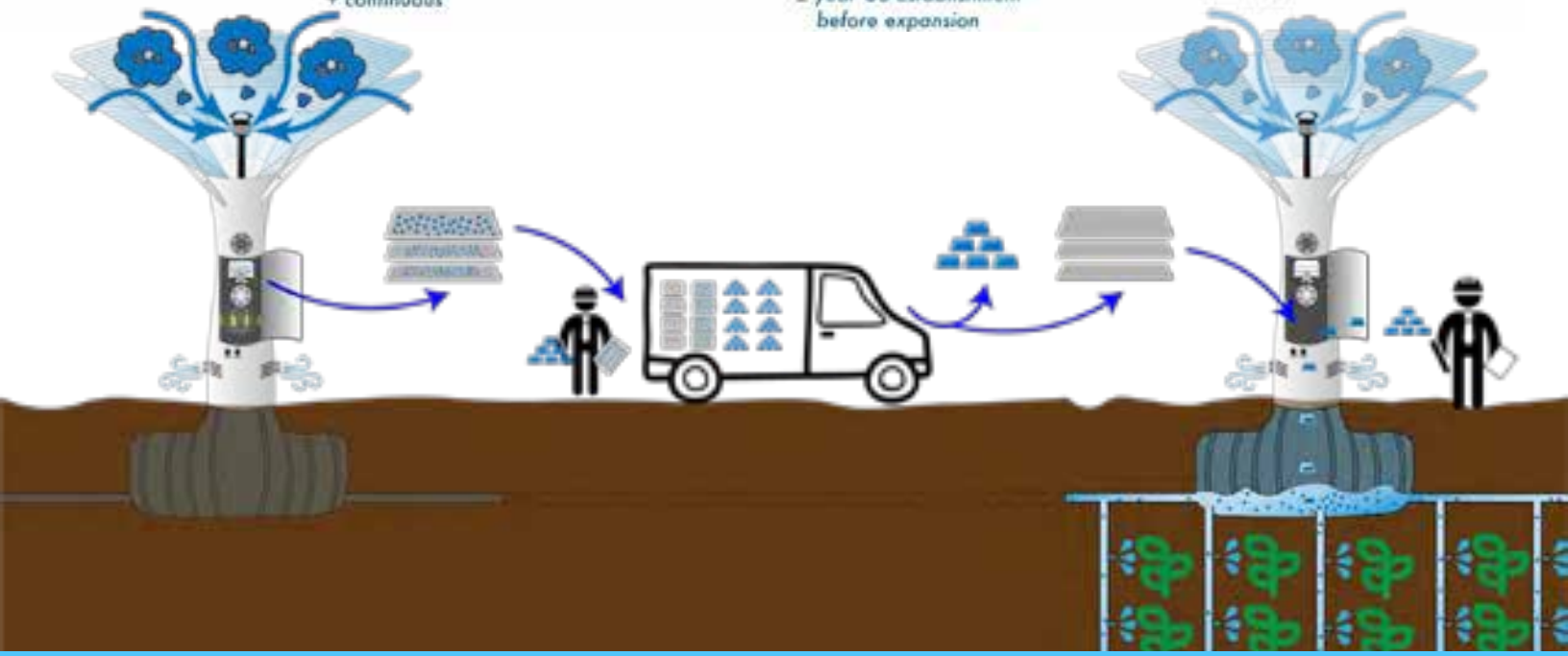
Invite OASYS users to agroforestry events as ambassadors for carbon sequestering technologies

Expand the new OASYS strategy around the world

~ 2 year US establishment before expansion

Change the way agriculture is approached worldwide

+ continuous



Service Design Package

Dispelling Concerns

Although we love this system, we fully recognize that the adoption of new technologies can be incredibly difficult for any party, especially those with existing systems that seem to already make life easier. After all, why buy into this high-tech, seemingly expensive system when mother nature's own trees could do the exact same thing at a fraction of the price? Well, after extensive discussions with our contacts in the industry, we've come to a great series of revelations that dispel those concerns.

"Why not just plant trees?"

This is easily the question we get the most often of all: if this system is meant to be an artificial tree, then why not just plant a tree instead? The reality of the situation is that while trees are incredibly effective at capturing carbon from the atmosphere, we need to plant more trees AND employ direct air capturing devices to catch up with climate change.

Yes, creating more forests can reduce soil erosion and increase biodiversity, but it cannot be scaled indefinitely because it requires lots of water and surface area. Additionally, the permanence of the moved carbon cannot always be guaranteed with trees: wildfires or deforestation can destroy the trees and release that carbon back into the atmosphere. putting us back at square one.

So, betting on solely trees as the solution to remove carbon dioxide from the atmosphere is a risky approach; by using direct air capture as a complementary approach to planting trees, we can diversify our options and have more control over how that carbon is used after it's been captured. Carbon dioxide removal via direct air capture is highly scalable as it requires only a small physical footprint and is fully measurable, permanent, and faster.

If trees are planted, it will typically take at least 10 years until the CO2 is removed from the air; DAC takes between 2 and 5 years to be completed.

TL;DR? Direct Air Capture is twice as fast as trees when it comes to the decarbonization of the atmosphere, full stop. Both are options, but deploying both at the same time is the solution.

Training & Maintenance

While this may seem like an incredibly complicated system with a ton of moving parts, at its core, it is fairly simple and functions perfectly well through automation. There are very few occasions during which a sure would have to directly interact with the system: pulling & replacing filters, accessing batteries, selecting power usage (dial), selecting carbon sequester rate (dial), and adding carbon cartridges.

The beauty of becoming an OASYS user is that as soon as you commit, you're never alone; this isn't just a product, it's first and foremost a service. The OASYS team walks you through the entire process of integrating the units into your land, from the initial meeting, to planning crops, to the rotation of seasons. They're just a phone call away at all times.

Not only that, but we've recommended that farmhands and other workers in OASYS locations receive special training from OASYS representatives to do extended maintenance if needed, so you always know you can make repairs in the event that there's an emergency.

Cost & Funding

While we completely understand that a piece of equipment may seem out of reach for many farming groups, especially those struggling to get by as a mid-sized farm, we believe the system as a whole is far more than what meets the eye.

We've developed a budgeting draft for the system that would not only allow farmers to easily access this service while on a budget, but also give them the support they may need should they choose to only use it for a set period of time. Introducing, the OASYS pricing model. A single OASYS unit and all its related services starts at a base price of $300 per month on lease, including all installation fees and consultation. Not only that, but upon installation, the user could come to an agreement to use the partial carbon sequestration system and get an overall discount on their fees. Beginning at 25% when used on "Low" constantly (meaning the filters would be replaced every 3 weeks), this is followed by 30% if used on "Medium" (replacement every 2 weeks), and finally a staggering 35% if used on "High" (weekly replacement). This discount certainly stacks over time, and since you get the carbon back in the form of the carbon cartridges free of charge, who would pass that up?

$300 per month

Base price on a lease.

Up to 35% Discount

Using the partial carbon sequestration system.

$1,500

For an outright purchase.

In the event a user chose to purchase an OASYS unit outright, we've estimated the cost would be approximately $1.5k for an outright purchase, but an additional investment would have to be made on a monthly basis for continued services in the form of maintenance and delivery.

"This still seems excessively expensive." We hear you, but in reality, OASYS really pays for itself. Think about it: as a whole, OASYS is a renewable energy source that can be redirected for equipment and building use, a brand new irrigation system that uses naturally occurring rainwater, AND a free fertilizer service. All these savings on regular expenses adds up, not even considering another factor here that could make the system completely free:

Monthly Maintenance

For additional services and delivery.

Carbon. Banking. Grants.

As of this year, the federal government has confirmed that it will be giving financial stipends to farm owners that employ at least two regenerative farming practices into their existing process. These could include simple agroforestry, rotating crops, etc., but why not just go the whole nine yards and do everything at once?

Carbon Banking Grants

Given to farm owners that employ at least 2 regenerative farming practices.

Implementation & Future Opportunities

OASYS as a whole has the potential to completely revolutionize the farming industry, giving agency back to farming professionals and supporting a system that is currently in collapse. With our farmable earth struggling to stay alive due to climate change and abuse, the integration of a solution like OASYS could address not one problem, but many by using resources efficiently and for a multitude of uses, just like our beloved Begonia pavonina.

We believe there are a few distinct areas where OASYS may thrive, including a main application and a series of potential alternative applications:

Main Application

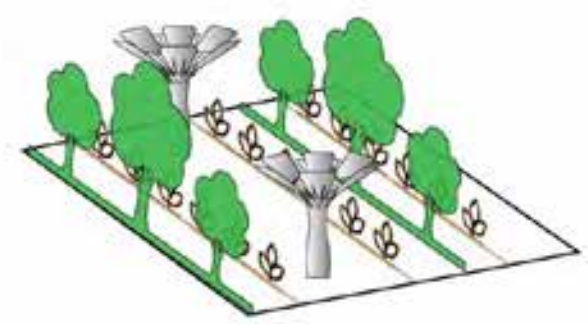
The MMD MSF Context

What: Agroforestry integration support for atmospheric decarbonization & specialty crop enablement

How: integration of the OASYS system in parallel with sapling planting

Where: Mid-Mississippi Delta region

Why: Providing the benefits of agroforestry while saplings grow



Potential Applications

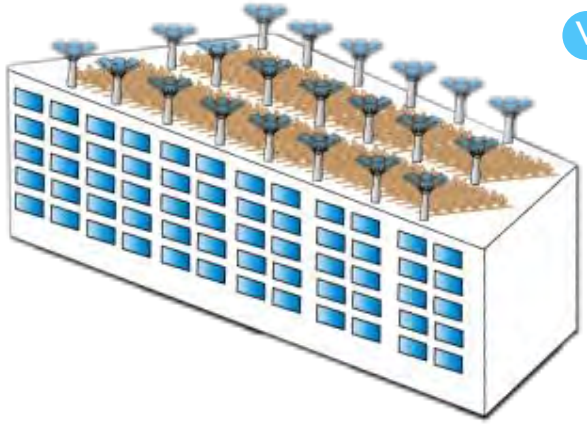
Rooftop Gardens

What: Stand-alone synthetic tree carbon sequestration system for rooftop agriculture

How: Integration of a pared-down OASYS system w/o irrigation cistern

Where: Urban rooftops (see Brooklyn Grange for example)

Why: Providing the benefits of agroforestry where trees cannot feasibly grow



Suburban Gardening

What: Stand-alone synthetic tree carbon sequestration system for backyard gardening & renters

How: Integration of a pared-down OASYS system w/o irrigation cistern

Where: Suburban housing's backyards (or for renters)

Why: Providing the benefits of agroforestry where long-term trees aren't able to be feasibly grown

Potential Applications

Carbon-Dense Highways

What: Stand-alone synthetic tree carbon sequestration system for carbon-heavy roadways

How: Integration of a pared-down OASYS system w/o irrigation cistern

Where: City blocks & highways where trees cannot grow (either due to limited space or root complications

Why: Providing the benefits of agroforestry where long-term trees aren't able to be feasibly grown

Potential Partners

Academic & Education

Systems & Tech

Services & Ambassadorship

OPV Films by ARMOR

Mizzou
University of Missouri

soletair power

5th World Congress on Agroforestry
Transitioning to a Viable World

CLIMEWORKS
Capturing CO_2 from air

SAVANNA INSTITUTE

Primary SDG's

Target 2.3: By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment

Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality

Target 9.2: Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries

Target 9.a: Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States

Target 9.b: Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities

Primary SDG's

Target 12.2: By 2030, achieve the sustainable management and efficient use of natural resources

Target 12.4: By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment

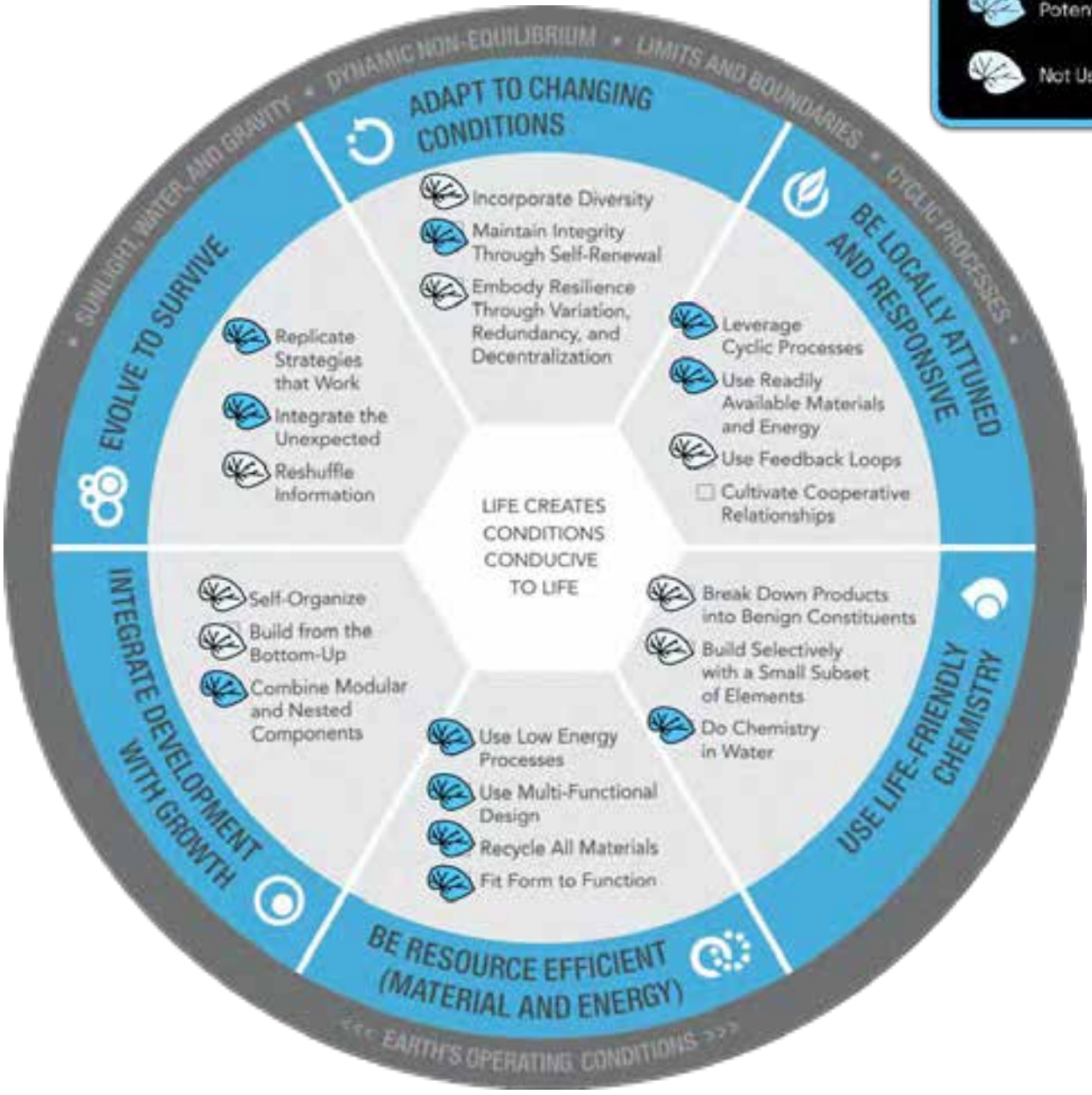
Sub-SDG's

Target 7.2
Target 7.a

Target 15.9

Target 17.17

Life's Principles



Projected Impact

The life of OASYS has more applications than we could possibly count, but the end result of mass execution is absolutely mind-blowing. Per our estimates, we believe that if every farm in America alone had about 5 OASYS units:

The equivalent of the released carbon from 230 million cars would be reabsorbed per year.

Farms become almost completely power independent.

Billions saved on fertilizer alone.

Thousands of jobs created.

Crops could be relocated & prevent supply chain collapse.

As we hope with all our projects we complete as a part of our SCAD education, we wish OASYS could come to life and positively impact our users. This hope is furthered by the area of study, sustainability & biomimicry methodology, both of which emphasize the importance of respect, study, appreciation, and action. Given more time and resources, making OASYS a reality would fulfill those goals and inspire others who come after.

SCAD

Biomimicry Methodology | Professor Scott Boylston

Thank You
For Reading!

Adero Brooks | Celine Diz | Em Cote | Erin Hull | Samiha Khan

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