Institute of Design

Spring 2023

Designing Investable Infrastructures for Controlled Environment Agriculture

Ana Dasgupta
Emery Donovan
Yong Hee Yoo
Ran Konaka
Sunaina Kuhn
Jorge Martínez Arana

Forward

Sustainable, equitable, and intelligent long-term investable infrastructure

One of the transformative forces in the 21st century is long-term capital investment that is shaping our economy, society, and environment for decades to come. Focusing on how capital is allocated and the decision-making processes happening to drive innovation, we examined how strategic choice-making through design can influence and shape the opportunity space and anticipate the future by imagining different investmnet cases. We explored the potential of EV charging and controlled environment agriculture from the lenses of sustainability, equity, intelligence, and investments. These infrastructures are at the nexus of multiple systems and the way they are shaped will play a major role in responding to complex issues like sustainability and equity faced worldwide.

In this report, we take a Research through Design approach to imaging new archetypes that anticipate the future, embracing these complex issues to operate at the intersection of multi-systems, stakeholders, levels, and intelligence.

Context

Long-term capital investment is a transformative force in the 21st century, shaping how we produce, distribute, and consume essential resources. Design is also a transformative force that shapes our experiences, systems, and mindsets. Yet they have traditionally been treated separately, to the detriment of both. To bring them together, we explored the potential of designing investable infrastructure through the lens of capital design.

Creating choices in complex and dynamic spaces requires bringing together multi-systems, stakeholders, levels, and intelligence. While designers are always interested in imagining new possibilities and asking, 'What if?' questions. This often requires exploring different options to make choices. Investors, on the other hand, are interested in decision-making. Finding what the right answer is, to be able to make a decision that minimizes risk and maximizes efficiency. While developing these projects, we combined these two perspectives through strategic choice-making to help develop effective, innovative, and investable archetypes through sustainability, equity, and intelligence lenses.

Infrastructure has many definitions. One might think about *hard infrastructure* like roads, bridges and power generation stations. Or one might consider *soft infrastructure*, like institutions, relationships and social interactions (Nogueira et al. 2020). The rise of intelligence embedded in everyday infrastructure plays a critical role in shaping and influencing our physical and social world and creating a space of algorithmic materiality that is highly complex. However, an emerging definition blends both aspects with an economic lens: *investable infrastructure.*

Investable infrastructure, at its simplest, means any fixed asset with a long-term cash flow. This could be an airport or toll road, but it could also include a salmon fishery, mushroom farm, ski hill or network of smart meters - and much more. Through this broad definition, much of our built environment becomes a fair game for design. Yet, to this point, the tools and frameworks for design to engage with investable infrastructure did not exist. The context of investment was important and crucially different from a business context. Notions of risk management, value creation and portfolio strategy all come into play. One of the goals of this class was to experiment and create those tools under the banner of Capital Design.

Context

Capital design posits that design can influence the trillions of dollars in investment from private long-term institutional infrastructure investment through a whole-view model of strategic choice and decision-making that maps strategic design capabilities against capital investment tools across known and unknown domains to assist portfolio construction.

To test this hypothesis in a bounded and controlled environment, the workshop selected two sectors to focus on controlled environment agriculture and electric vehicle charging. Not only have these systems attracted billions of dollars in investment over the last five years, but they also represent the intersection of multiple trends, drivers, systems and forces that will shape our economy, society and environment for decades to come. These forces include the “3Ds” of digitization, decarbonization and decentralization.

Controlled Environment Agriculture (CEA) “uses technology to enable growers to monitor and control a crop’s environment to desired conditions”, according to the University of Arizona Biosystems Engineering Department. Greenhouses, aquacultures, hydroponic farms, and vertical farms are all examples of CEAs. Moreover, when viewed through an investable infrastructure lens, CEA includes the production of agricultural products, and the post-production supply chain up until consumption or the beginning of the food manufacturing process.

Transportation and mobility are a big infrastructure investment focus and a core lever in global decarbonization. Fundamental shifts in mobility and transport subsectors driven by EV technological maturity, consumer demand/behavior, international government support, auto OEM commitments. Electric Vehicle Charging (EV charging) - similar to CEA - started out as the individual charging stations for electric passenger vehicles. As such, the potential shift from “how do we replicate gas stations for EVs?” to “what should we electrify?” offered significant opportunities for the workshop to design investable infrastructure in novel and productive ways. The class considered many aspects of EV charging, from battery storage, point charging, e-mobility and vehicles-as-a-service, and other innovative uses.

Context

To carry both projects forward, we adopted Research through Design approach to unfold the complexity when looking at everyday infrastructures to embed strategic intent while designing at the nexus of multiple systems, stakeholders, levels, and intelligence. Both projects went through a series of multiple prototyping rounds building off of each other and producing a total of sixteen different prototypes each representing a unique archetype. Each round of prototyping was initiated by a prompt to guide the design process to strategically explore both the opportunity and problem space. After leading the reasoning through a sequence of individual grounded prototypes to create choices, the last round was centered around evaluating the choices that were created and combining them into bundles of features to create unique investable archetypes.

The whole process was carried through multiple frameworks and tools to navigate the complex space of innovation. Asset Mapping, Life Supporting Model, Archetypes, Anti-Oppressive Framework, Narratives, Causal Loops, Action Situations, and Anatomy of Infrastructure were some of the tools that were mainly used to center the archetypes through the lenses of sustainability, equity, and intelligence.

This report is the culmination of a semester's worth of work of masters of design students who have helped establish a new focus for design. We hope readers of this report share our cautious optimism for the future in how design can influence one of the most powerful forces that impact all aspects of our lives.

Table of Contents

Introduction

01

The Future of Food

The agricultural systems of the 20th century are not designed for the 21st century. Growing social inequality, surging global populations and the increasing impacts of climate change threaten the fragile, extractive infrastructures that produce the majority of the world's food.

In this project, we explored how this global context, as well as the growing forces of decentralization, digitization and decarbonization ("the 3 Ds") will shape food infrastructures of the future. Using a Research through Design approach, we identified several unique investment opportunities for Controlled Environment Agriculture (CEAs). In this report, we detail two of these opportunities - sustainable protein production and emergency services for agriculture - and the unique features that make these promising investment opportunities.

What is a CEA?

In Controlled Environment Agriculture (CEA) systems, growers use technology to monitor and optimize the conditions for growing crops.

Greenhouses, aquacultures, hydroponic farms, and vertical farms are all examples of CEAs. When viewed through an investable infrastructure lens, CEAs may also involve the production of agricultural products, as well as the post-production supply chain and the beginning of the food manufacturing process.

Especially as technologies continue to improve, CEAs offer a tremendous opportunity for increasing the efficiency, sustainability and reliability of global agricultural systems.

What is investable infrastructure?

The decisions that investors make about how to distribute and invest their financial resources are a major force shaping the future. When determining where to invest, infrastructure investing is a uniquely exciting opportunity in that it can be more innovative than more traditional forms of investing but not as risky as tech investing.

As designers, our skills are best leveraged by exploring future opportunities for investable infrastructure. Similar to an architect exploring all possible configurations for houses of the future, designers can then give this specific list of criteria to investors, who act like real estate agents and search for these particular types of homes that they would otherwise not have known could be built if not for their collaboration with designers.

Identifying Opportunities

Using a Research through Design approach, our team conducted eight rounds of rapid prototyping to explore opportunities for investable infrastructure built around CEAs. This process allowed us to identify the following opportunity areas for the future of agriculture:

- Centering food production closer to population centers
- Prioritizing animal welfare in protein production
- Scaling the production of sustainable sources of protein
- Building AI tools to improve farmers' DEI and sustainability decisions
- Leveraging data to increase food production efficiency
- Implementing nutrient exchange services
- Reusing existing infrastructures
- Building mobile and modular CEAs
- Creating a global network of digitally connected CEAs

Envisioning a better food future

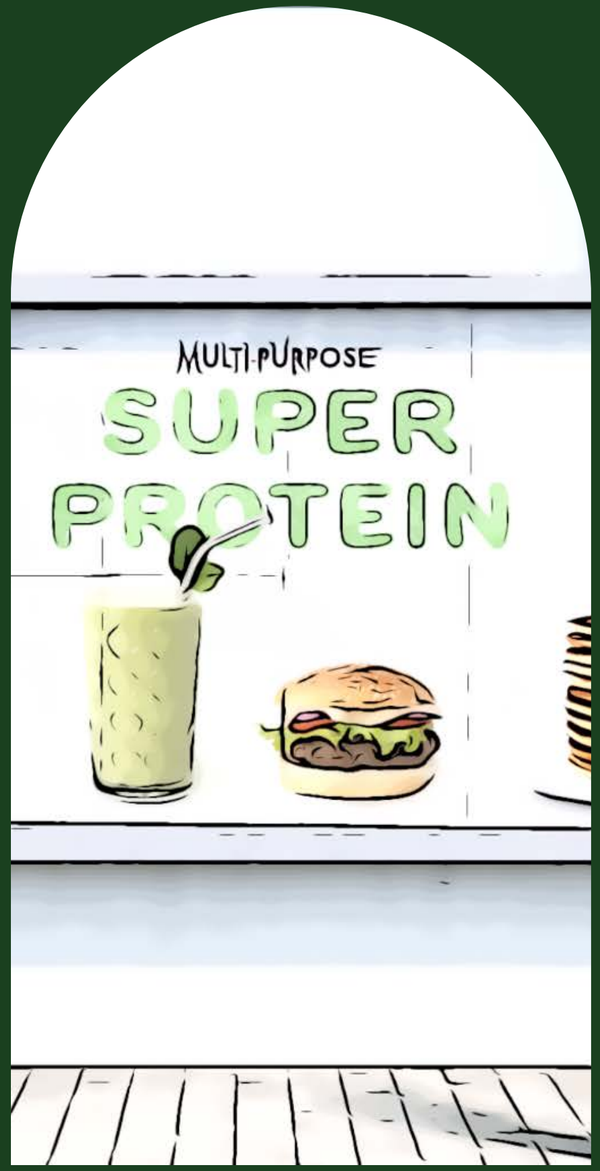
From...	To...
Narrow default mindsets about food ◦ Consumers don't know about where their food comes from ◦ Good food is expensive ◦ Farmers and workers intimidated by data	**Expanded mindsets** ◦ Educating consumers about food origins ◦ Incentivizing behavior change to buy more ethically sourced crops ◦ Educating farmers/workers about AI/data
Centralized black box sites of production ◦ A few actors control most of the production ◦ Lack of transparency about system	**Resilient networks** ◦ Decentralized networks built around CEAs ◦ Expanding partnerships with new actors (e.g. people who are incarcerated, pet food companies, large companies) ◦ Data-driven transparency in all systems ◦ Making ethical food affordable
Decisions driven by profit ◦ Good food is expensive and out of reach ◦ Human, animal and planet costs not accounted for in final price	**A values-driven infrastructure for producing food** ◦ Fixed asset with long term cash flow via long term B2B contracts subsidize creation of new infrastructure ◦ Creating value from waste, closed loop systems, nutrient exchange services

Design Principles

An analysis of the eight prototypes revealed that it is not enough to propose a CEA as a technological solution within a broken food system. Instead, for a CEA to be an investable infrastructure, it must be situated within a larger values-informed ecosystem. Our research suggests that any new CEA investable infrastructure must:

- Promote justice
- Ensure transparency
- Decentralize food production
- Foster increased resilience
- Expand stakeholder networks
- Create value out of that which isn't currently valued
- Shift default mindsets and behaviors around food

We chose two projects for further development based upon the degree to which they embodied these design principles. They are detailed in subsequent sections of this report.



Sustainable Superfood

02

Opportunity:
Why Edible Insects

$9.60 billion

industry by 2030

28.3%

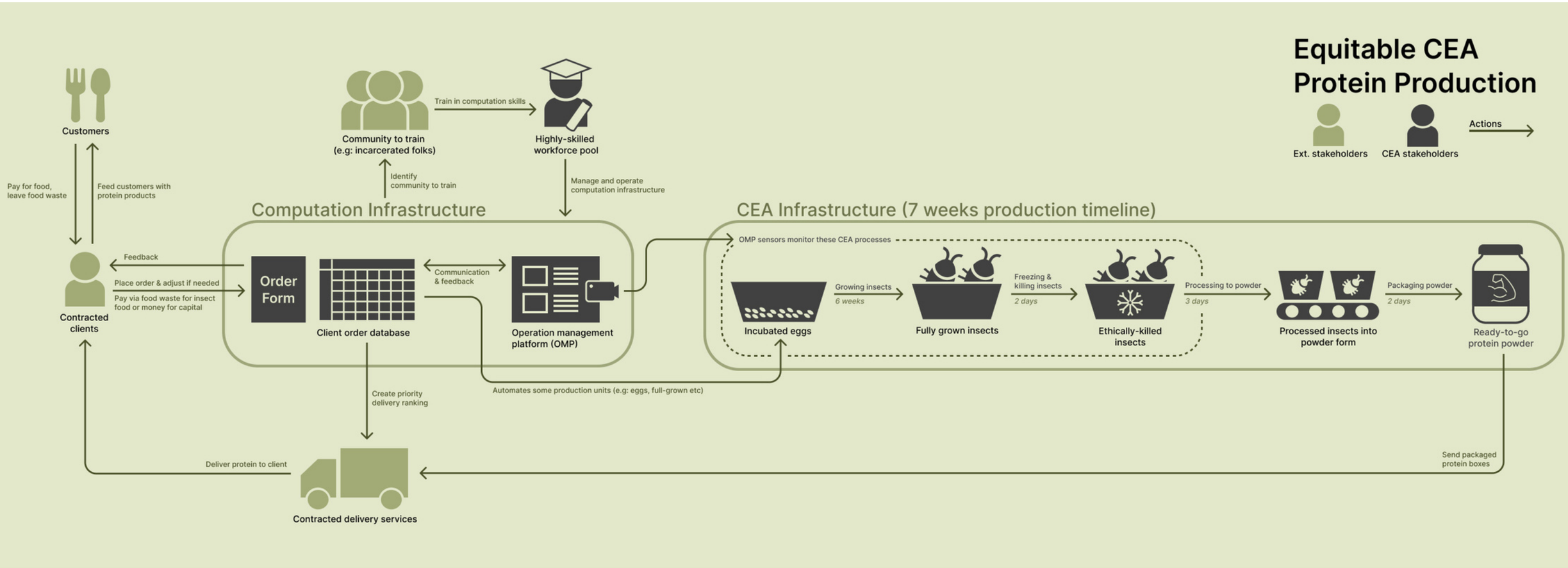
estimated Compound Annual Growth Rate

The growth of the edible insects market is driven by the increasing greenhouse gas emissions from the livestock and poultry industries, the high nutritional value of insects, the environmental benefits of consuming edible insects, the rising demand for insect-derived protein in the animal feed industry, and the minimal risk of transmitting zoonotic diseases with the consumption of edible insects.

Furthermore, emerging economies are expected to provide significant growth opportunities for the players operating in this market. However, a lack of awareness regarding the benefits of insect consumption is expected to remain a major challenge for the growth of this market.

*Source

System Map


Equitable CEA Protein Production
Ext. stakeholders
CEA stakeholders
Actions
Customers
Pay for food, leave food waste
Feed customers with protein products
Community to train (e.g: incarcerated folks)
Train in computation skills
Highly-skilled workforce pool
Identify community to train
Manage and operate computation infrastructure
Computation Infrastructure
CEA Infrastructure (7 weeks production timeline)
Feedback
Place order & adjust if needed
Pay via food waste for insect food or money for capital
Contracted clients
Order Form
Client order database
Communication & feedback
Operation management platform (OMP)
OMP sensors monitor these CEA processes
Incubated eggs
Growing insects
6 weeks
Fully grown insects
Freezing & killing insects
2 days
Ethically-killed insects
Processing to powder
3 days
Processed insects into powder form
Packaging powder
2 days
Ready-to-go protein powder
Automates some production units (e.g: eggs, full-grown etc)
Create priority delivery ranking
Deliver protein to client
Send packaged protein boxes
Contracted delivery services

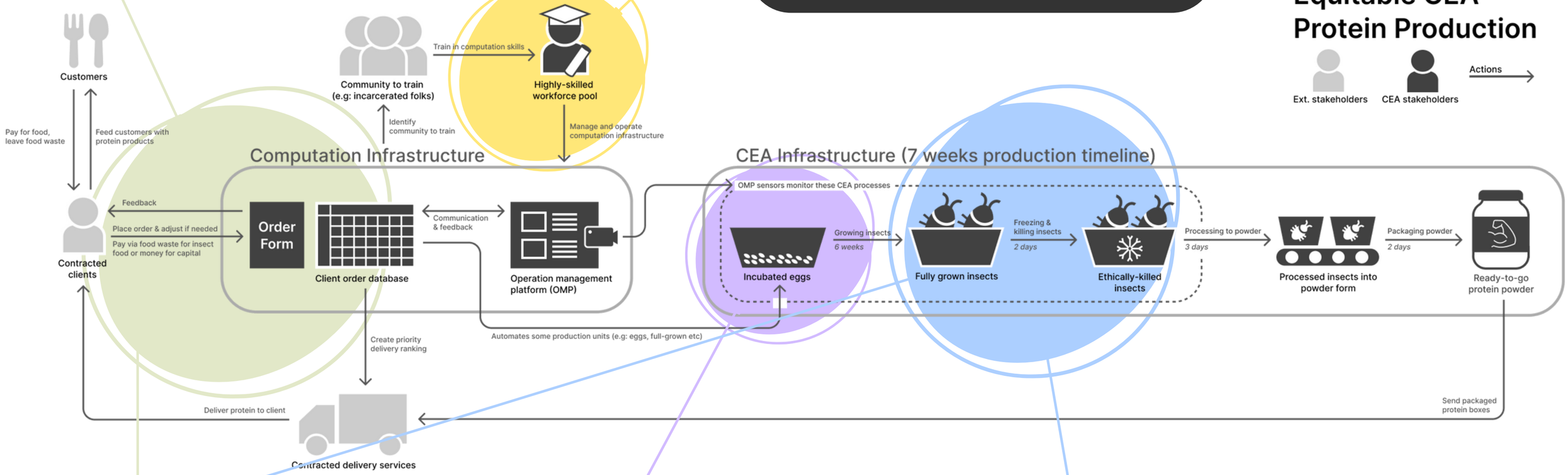
Prioritized Fulfillment & Delivery

Customer orders are prioritized for processing and delivery based on an equity score that are assigned at sign up.

Workforce Development

Employment opportunities for formerly incarcerated people is prioritized to provide job training in the managements of CEAs.

Equitable CEA Protein Production



Data into Intelligence

Both the processing of orders, as well as the environmental and health conditions of the insects are monitored & maintained for optimal results through automation.

Insect Protein

The CEA is used for the production and processing of insect to produce a more sustainable protein that has a range of consumers markets

Humane On-Site Processing

The CEA system performs an end-to-end service; insects are grown, humanely harvested (a two step method of cooling to induce hibernation, and freezing), and processed into powder for final purchase.

Restaurant Partnerships

In a fancy restaurant in the suburbs of Chicago, the menu features items that include or are supplemented with insect protein to pack a higher nutritional punch. The waiter has recommended pancakes, which are made with cricket flour. His recommendation is based on their low carbon footprint, dense nutritional profile and pleasing flavor.

Easily Adoptable Food
Insect protein can be used to supplement food and be adopted by mulitple markets, including high-end restaurants and pet food to name a few

Insect Quality of Life

The lives of the insects are treated with respect in both their environments and their deaths. Automated monitoring of insect environments registers the health, size, weight and overall activity of an insect to ensure that an insect is content and happy in the living conditions.

Hibernation

Insects are harvested by reducing the temperatures in their environment to a degree that initiates a natural hibernation process. Once the insects have gone into hibernation, they are removed from the living environment and frozen in large freezers, effectively being killed while in a state of sleep and without experiencing stress or fear.

Job Training

People who are incarcerated undergo job training to help prepare them for life after prison and attain a concrete tech skill in the management and oversight of insect CEAs.

Training modules are designed around motor skills, decision making, problem solving, data and computation literacy and management, in addition to other transferable skills that can be utilized in a number of different industries.

Computational Literacy

Job training includes ensuring a safe and healthy environment for the insects, and monitoring their overall well being as well as making informed decisions when data and intuition clash.

Agro Alliance

A resiliency-building network for farmers

03

Opportunity:
Why Agro Alliance

$3.1 billion

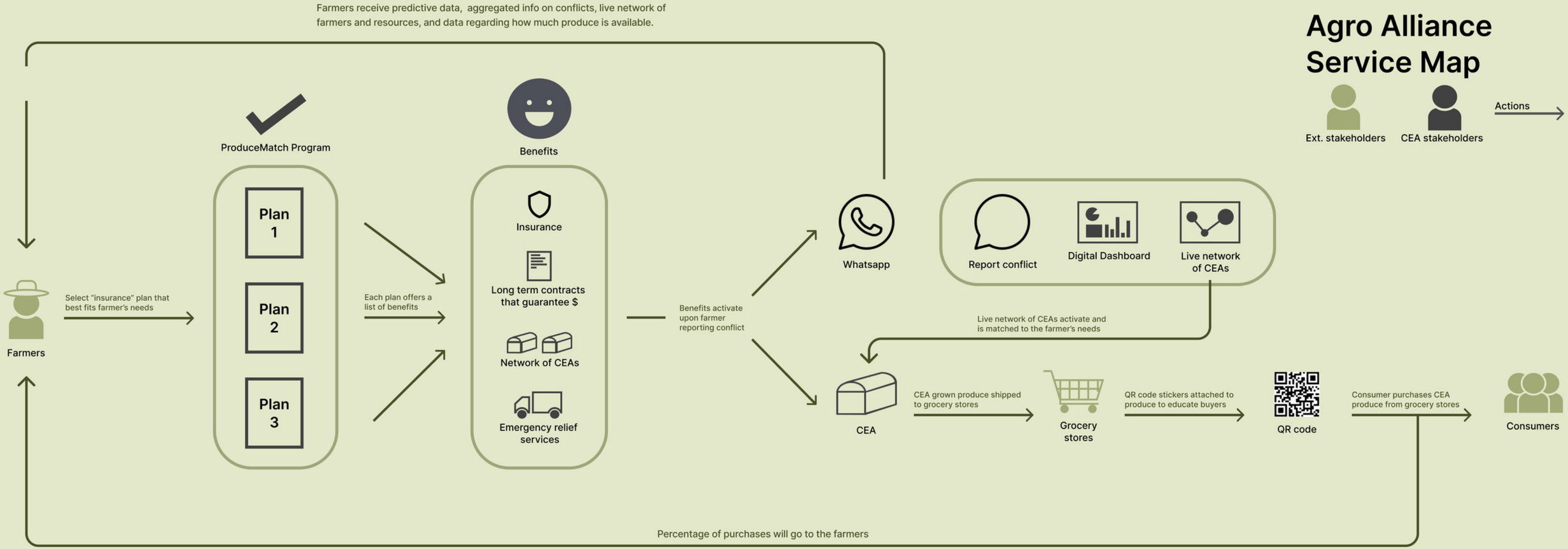
avocado imports from US to Mexico in 2022

Source

Although many people around the world enjoy eating avocados, far fewer are aware of the many challenges in the avocado supply chain. For example, many avocado growers in Mexico are extorted by criminals who seek to take advantage of this highly concentrated and lucrative industry. The economic pressure to meet selling quotas combined with low formal political authority puts growers in a marginalized position.

In situations like this, as well as in cases of environmental disaster (which will become increasingly common due to climate change), farmers need services that will provide them with financial security, emergency services and cooperative networks of other growers who can cover their production needs when their farms are out of commission. Agro Alliance is a global CEA-based network that provides farmers with these specialized services.

Service Blueprint

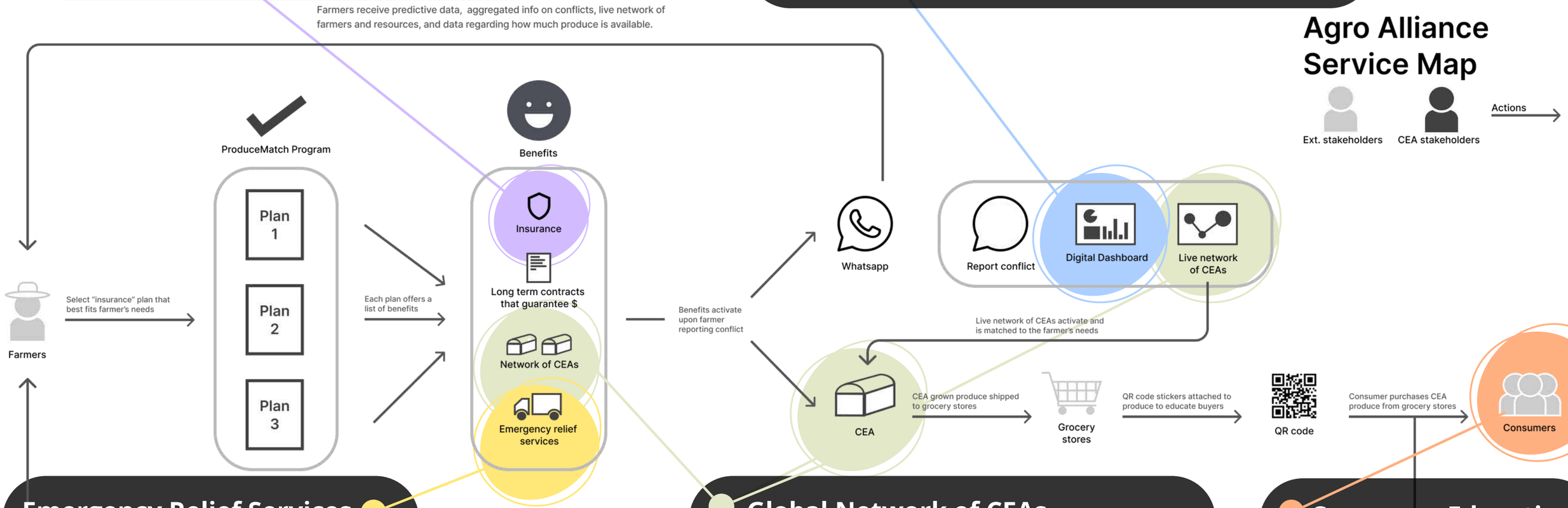


Financial Security

Like insurance, farmers are guaranteed a basic income in the face of a crisis that debilitates production of crop on their farm.

Grower Safety Through Data Aggregation

Data on conditions is gathered from farmers, NGOs and satellites in order to create a clear, multi-dimensional picture of the current climate as well as predict future trends and dangers.



Emergency Relief Services

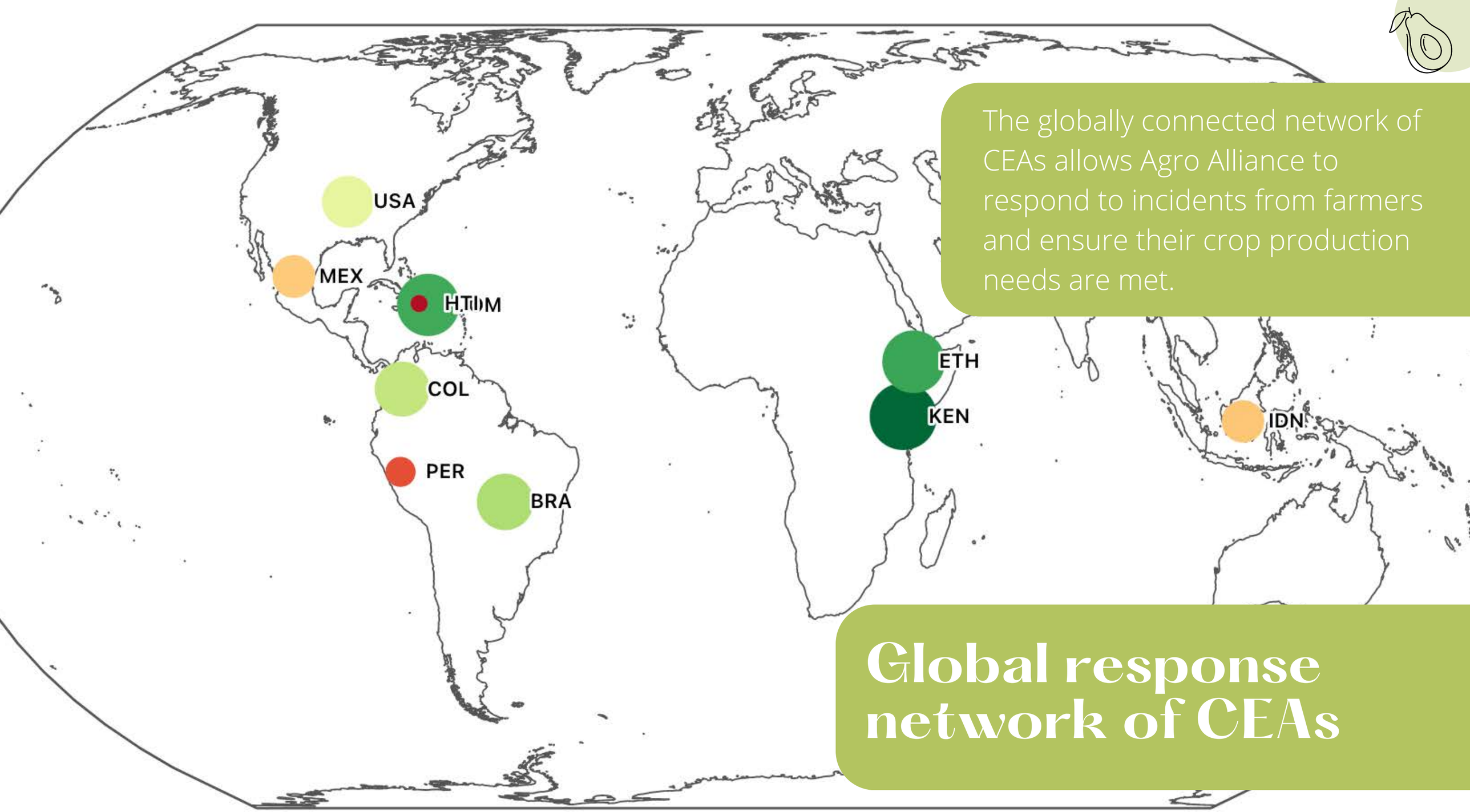
When emergencies strike, immediate basic needs relief is available, followed by other tiers.

Global Network of CEAs

The network allows Agro Alliance to respond to incidents from farmers and cover their crop production needs.

Consumer Education

Consumers learn about the supply chain via QR code stickers.



The globally connected network of CEAs allows Agro Alliance to respond to incidents from farmers and ensure their crop production needs are met.

Global response network of CEAs

Like insurance, farmers are guaranteed a basic income in the face of a crisis that debilitates production of crop on their farm.

Financial security

MEET DENNIS.

HIS FARM GOT HIT BY A DROUGHT.

Meet Dennis, avocado farmer from Tanzania who recently lost 40% of his farm from a nation-wide drought. Typically, Dennis produces ~190,000 lbs of avocado per year. This year he was only able to produce ~121,000 lbs of avocado.

Through Agro Alliance's **ProduceMatch Program**, Dennis was able to reduce his farm financial pressure, and make up for the majority of his otherwise lost produce.

AGRO ALLIANCE

When conflict or environmental disasters strike, farmers receive relief in the form of economic, material and informational aid.

YOUR PURCHASE AIDED DENNIS

Each purchase contributes to the aid of avocado farmers.

To learn more about **ProduceMatch Program**, visit AgroAlliance.org

Emergency relief services

Grower Emergency Hotline

On an avocado farm in Mexico, Alejandro Herrera is part of the U.S.-based program that insures farmers, and guarantees they receive an income when their harvest fails as a result of a crisis.

As part of the network, Alejandro has access to an emergency WhatsApp hotline. When his crop production was much lower than expected last year because of drought, he was able to immediately report this situation and receive assistance in the form of crop relief, specialized advice and insurance-based income.

Incident Report
A live Agro Alliance representative provides customized advice and support to farmers via 24/7 WhatsApp chat functions.

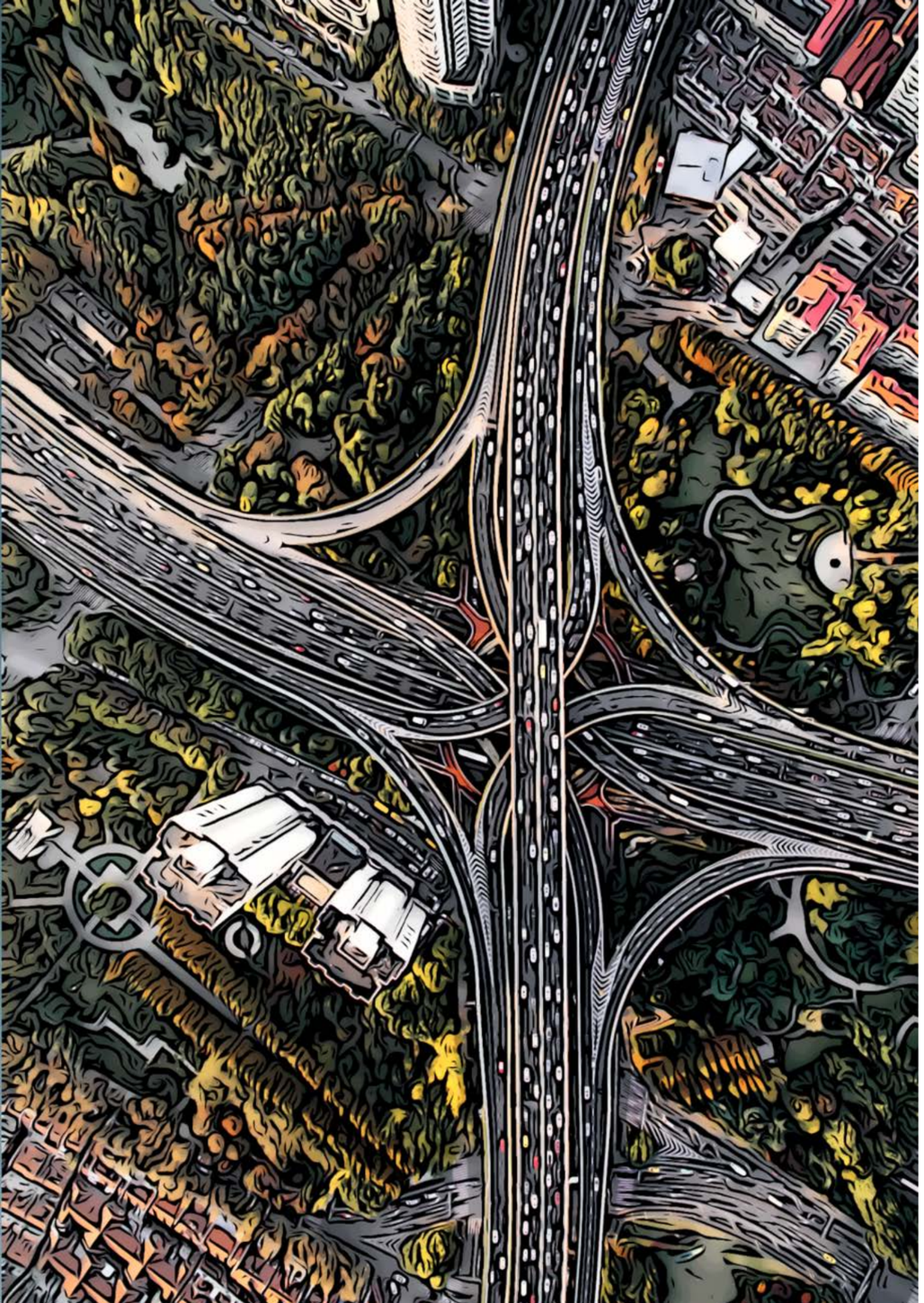
Consumer Education

In a grocery store in the suburbs of Chicago, a customer is trying to decide which kinds of avocados to purchase for her family's weekly salads and smoothies. After holding an avocado in her hands to check ripeness, she uses her phone to scan the QR code on the sticker. She learns that the avocado she is holding was grown by a farmer in Tanzania. He joined the Agro Alliance after a drought decimated over half his crops. The customer is surprised to learn that avocado growers face such harsh conditions and is happy to purchase this avocado in support of this ethical supply chain, especially since it's the same cost as the conventional avocados.

QR Code
The Agro Alliance sticker that is on each avocado links to a poster campaign educating consumers about ethical supply chains.

Conclusion

04



Investment can make a better future real

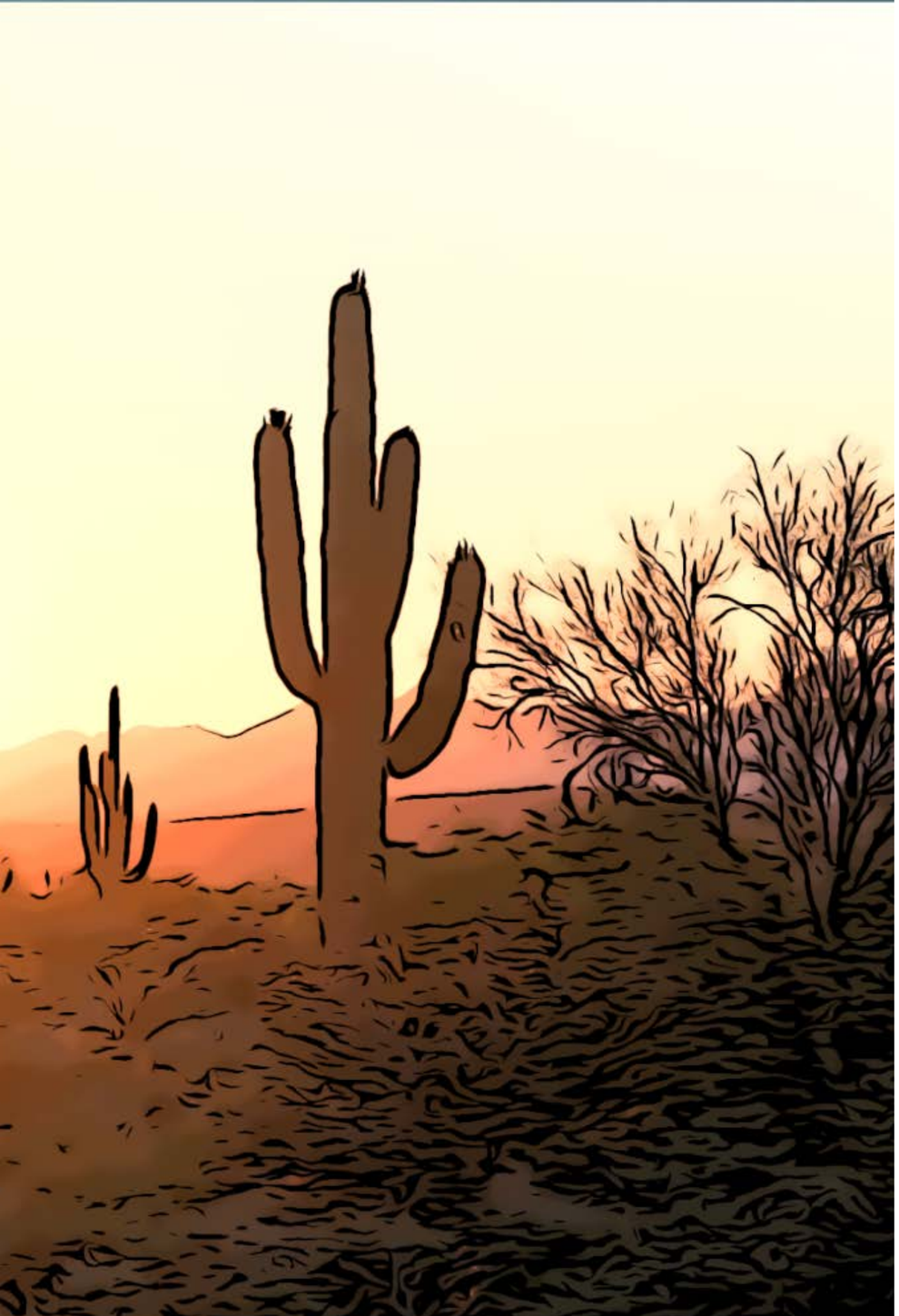
A more just, sustainable and resilient food future is possible. Infrastructural investment decisions have the power to be a headwind (actively working against), tailwind (actively supporting) or neutral force (which by default supports the status quo) in relation to this imagined future.

It is our hope that investors take seriously the opportunities we have outlined here for arriving at this more desirable food future. We are enthusiastic about these proposals to scale sustainable protein and build emergency infrastructures for farmers because of their strong potential to expand mindsets, build resilience and create thriving for all.

Thank You

Appendix

05



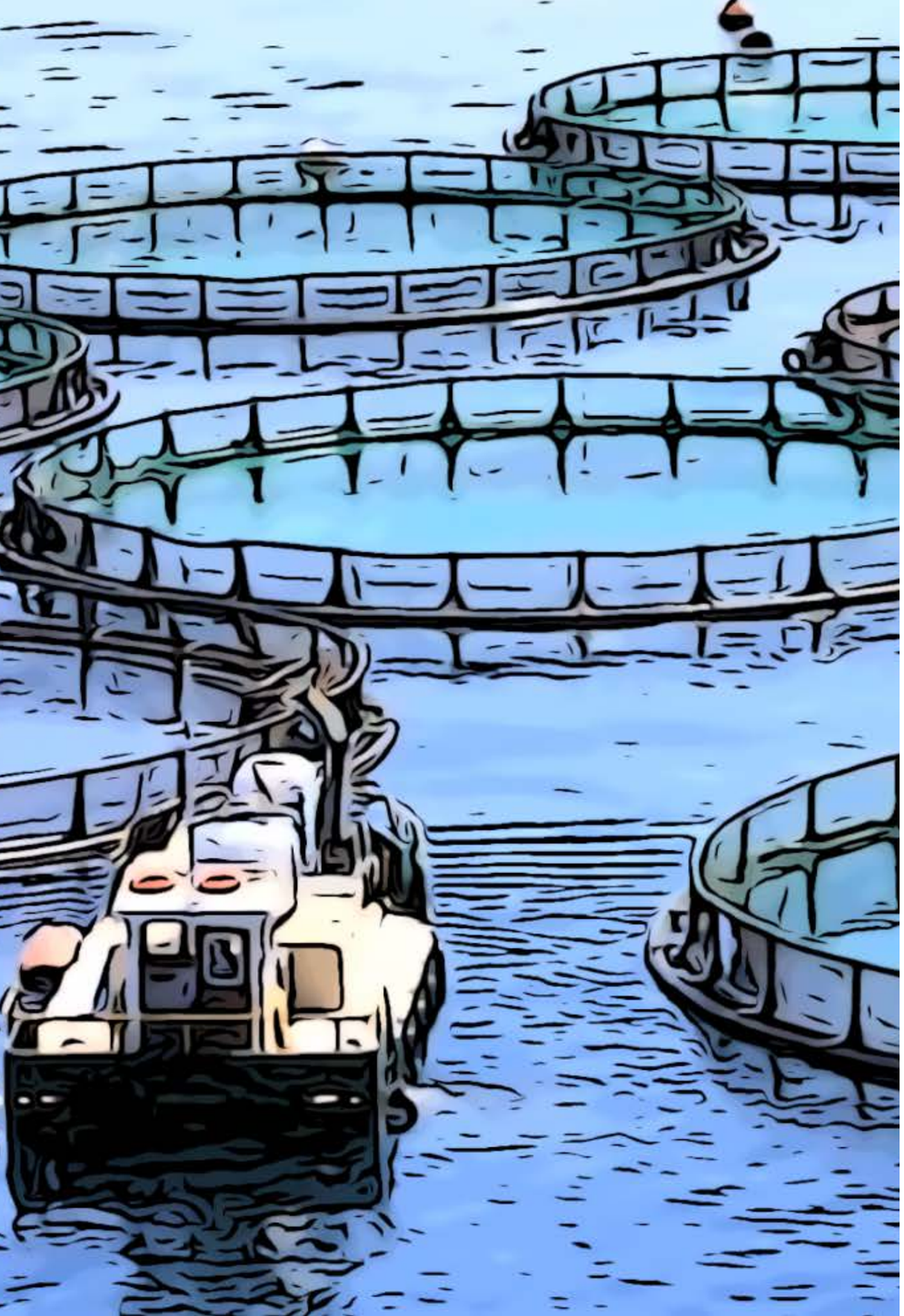
Prototyping Prompt 1

How might we design a controlled environment agriculture solution for a **fast-growing, yet drought-stricken city like Phoenix, Arizona**? Space is relatively plentiful on the outskirts of the city, however access to key inputs (water, fertilizer, electricity) are subject to fluctuating markets and may be in short supply.

Prototyping Prompt 2

The future of infrastructure will be decarbonized, decentralized, and digitized. Sustainability, equity, and capital are three risk factors that must be accounted for. **Given these assumptions, find and frame an opportunity space where you think Controlled Environment Agriculture has a high potential of being an archetype that anticipates the future.**

In essence, you are being asked to prototype the 'what' and 'how' as a way of presenting/explaining the 'why.' Frame this as 'What if...?' and prototype the critical features of the archetype as the response to this opportunity space. Provide the reasoning behind your suggested archetype. As a prompt, you can, for instance, start with "What if we '3D' farm-to-table? How and why?"



Prototyping Prompt 3

Infrastructure is always changing, yet two things remain true: humans have always needed to generate, move and store things; and infrastructure emerges from the interaction of human and non-human agents. **With this in mind, develop a concept for investable infrastructure in Controlled Environment Agriculture for *aquaculture*.**

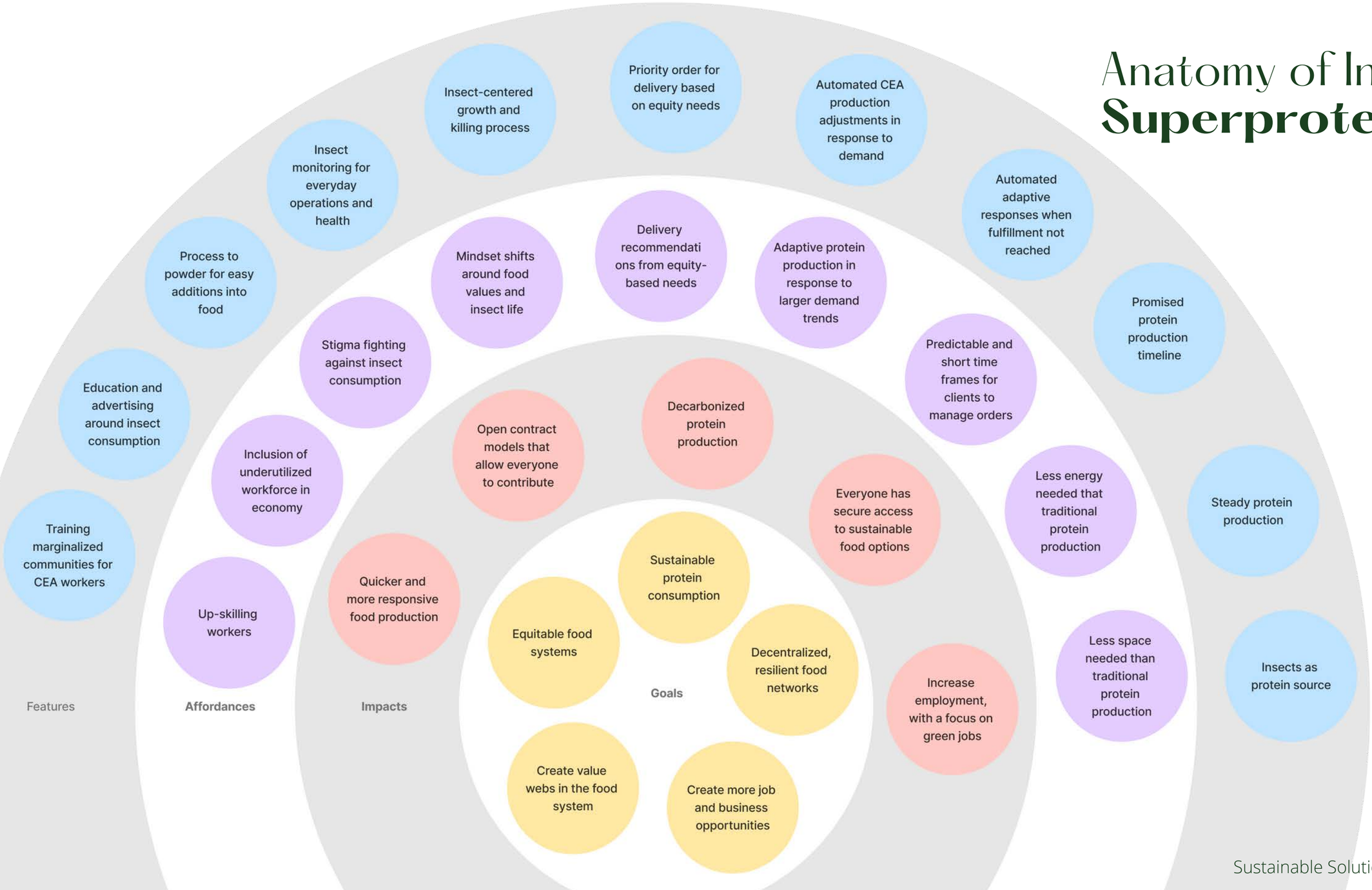
Consider focusing on one, or a combination of, the three core human needs and agents that necessitate infrastructure. Explain and describe which aspect you incorporated, and why. You must define and explain where to play and how to win. **Your investable infrastructure must be aligned with the 3D forces shaping infrastructures (digitize, decentralize, and decarbonize) as well as the 3 fundamental functions of infrastructure (generate, move, and store).**

Prototyping Prompt 4

Infrastructure is always changing, yet two things remain true: humans have always needed to generate, move and store things; and infrastructure emerges from the interaction of human and non-human agents. **With this in mind, develop a concept for investable infrastructure in Controlled Environment Agriculture for *land based protein*.**

Consider focusing on one, or a combination of, the three core human needs and agents that necessitate infrastructure. Explain and describe which aspect you incorporated, and why. You must define and explain where to play and how to win. **Your investable infrastructure must be aligned with the 3D forces shaping infrastructures (digitize, decentralize, and decarbonize) as well as the 3 fundamental functions of infrastructure (generate, move, and store).**

Anatomy of Infrastructure **Superprotein CEAs**



Anatomy of Infrastructure: **Agro Alliance**