Sustainable and forward-thinking food systems

BCG hello tomorrow

Report 1

Sustainable and forward-thinking food systems

New projections by the United Nations forecast a world population of 8.6 billion in 2030, and 9.8 billion by 2050. With about 83 million individuals added to the world's population every year, constraints on cities, supply chains, and food systems have never been greater [1].
The challenges we now face are changing the ways in which we produce and eat our food. Limited resources, shifting consumer behaviors, and technological advances have encouraged the adoption of new practices, allowing deep tech to slowly gain footing amidst long-established traditions.
This year, deep tech pioneers have showcased innovations which can be summed up by three intersecting trends:

1.1 Taking care of our food's food

Increasing knowledge of our food systems and their impacts on planet and consumer health has raised interest, if not concerns, in agricultural production. Reducing reliance on chemicals, limiting waste, and efficiently using resources are now some of the biggest challenges agriculture must tackle. The modernization of agriculture through the use of technology-enabled solutions has propelled the industry towards what is referred to as "precision agriculture" – the safest bet yet for tending to our food and, in the long run, ourselves.

1.2 From lab-to-fork: making cultured everything a reality

With knowledge of planetary boundaries, rising concerns regarding animal welfare and changes in diets, protein production is on its way towards change. Technological advances in food science have allowed pioneers to showcase what could likely be the future of food. Cellular agriculture will venture out of the meat field, microbes will grow specific compounds, and consumer-centricity will peak with personalized nutrition.

1.3 Food systems as agents of sustainability in the global supply chain

Though fully integrated into our global supply chains, food systems are nevertheless major contributors to their own inefficiency. A lack of structure, information, and polluting habits have exposed the industry's bad practices and the resulting negative impact on consumers. New technologies are already being developed to drive change by using resources efficiently, limiting – if not eliminating – waste, and monitoring overall agricultural activities, both here on Earth and in space.

Sustainable and forward-thinking food systems

Why it matters

Studying our current food systems, the United Nations recently identified three important challenges the world needs to address over the next decade: eradicating hunger, producing more food with fewer resources, and feeding ourselves more sustainably.
The world's population is expected to grow from 7.3 billion to 8.5 billion people by 2030. As a result, by 2050, global food production will need to increase by more than 70% with just 5% more agricultural land available. To make things worse, currently 20% of the world's protein is consumed by farm animals rather than humans, as the world's supply of fish, water, and soil resources continues to decline. Therefore, with every intention of feeding the planet of tomorrow, while also meeting global climate and sustainability goals, there is an overarching need to increase protein productivity. Individuals can contribute towards this positive shift by leaving behind society's oldest dietary habits and adopting a more desirable plant-based or alternative protein diet.

Why is it important to play the ecosystem game?

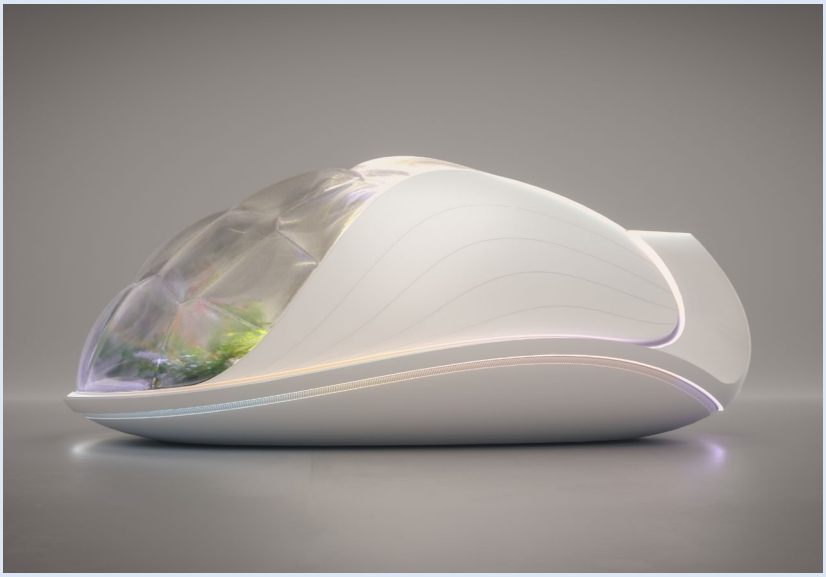
As we shift towards a more innovation-driven culture, the agricultural industry will need to adapt and take advantage of state-of-the-art practices developed by deep tech startups to collectively overcome the many challenges ahead. Key players in both the agriculture and food industries will be at the forefront of the food system revolution by way of leveraging greater data valorization, connectivity, and monitoring, as well as advancing an ecological transformation through alternative inputs and proteins. With fragmented and highly-regulated systems in place, the agricultural industry remains a complex market for deep tech startups. Several of them, such as Ÿnsect (insect-based animal protein) and Impossible Foods (lab-grown meat), have, in a relatively short time span, managed to cut through and become key players in complex value chains. To ensure that smart agricultural solutions like these can get to market in a more timely fashion, collaborative relationships between institutions, stakeholders across the food chain, and deep tech startups will be necessary. With this unified approach, they will be able to better shape current agricultural regulations, both locally and globally.

Overview of trends

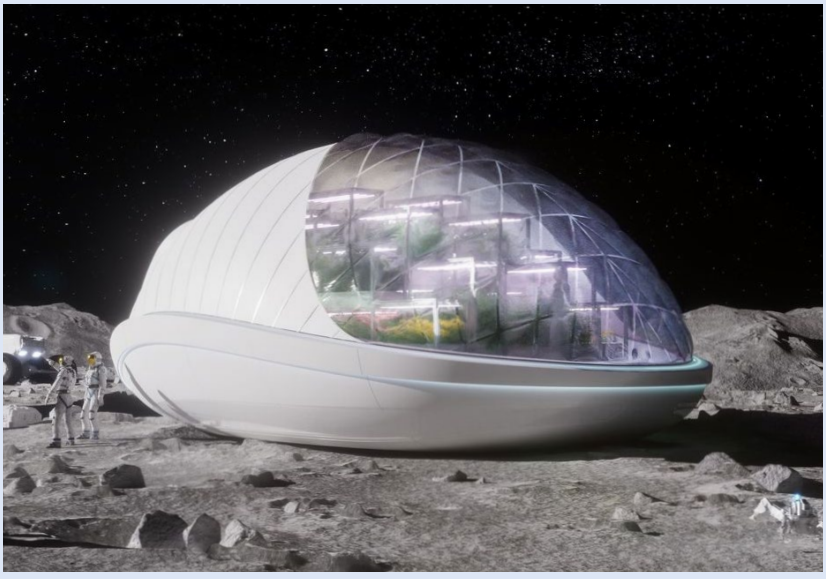
This year, deep tech pioneers have showcased at an unprecedented level the possibilities offered to us by new technologies in food and agriculture. This is exemplified through the development of novelty feed with maximized nutrition and absorbability properties, as well as by advancing precision agriculture that has led to a better understanding of crop and soil wellbeing and longevity (see page 7). Furthermore, the smart thinkers and doers have allowed us to scale up the production of lab-grown cultured proteins by means of developing more efficient bioinks and bioprinting solutions. This has helped drive consumer adoption through innovative flavor-enhancing technologies, produced from optimized cultivated fat (see page 11). Overall, deep tech is illuminating potential changes to a more resilient and sustainable global food supply chain, which involves more precise carbon footprint monitoring, microbe protective packaging, and detection of bioactive ingredients from waste streams (see page 15).

What's next to watch?

With more than 80 deep tech pioneers addressing Sustainable and Forward-thinking Food Systems, a clear trend to keep an eye on is the adoption of space and military inventions in agriculture. Solutions covering both terrestrial and extra-terrestrial applications could bring about new perspectives, as well as provide new market opportunities to both learn and grow.



Interstellar Lab developed the BioPod, an air-supported dome equipped with an advanced water, air and crop cultivation system that automatically regulates air, pressure, water, temperature, and humidity to recreate ideal environmental conditions for sustainable food production, plant cultivation, and biodiversity preservation.



Trends' expected time to market [2]

2028

2026

2024

2022

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Taking care of our food's food

BioFeyn » Improving the health and sustainability of farmed fish through feed

Fotenix » Enabling the smart operation of agricultural machinery by using smart cameras

LLEAF » Allowing growers to harness the power of sunlight in greenhouses

Soil Carbon » Microbial seed coating to capture and store stable carbon forms in agriculture

page 12-13

From lab to fork: making cultured everything a reality

Cultured Decadence » Real crustacean meat created directly from animal cells

Cocuus System Iberica » Plant or cell-based animal protein analogues using 2D/3D laser printing, bioprinting and robotics

Hoxton Farms » Growing real animal fat, without the animals

California Cultured » Lab-cultured cocoa flavanols and edible chocolate

page 16-17

Food systems as an agent of sustainability in the global Supply chain

Crover » Underground drone helping grain storage operators maintain the quality of their stock

GreenPod Labs » Active packaging to extend the shelf life of fruits and vegetables

Kosmode » Extracting bioactive ingredients from plants and food waste-streams to (re)create food

CarbonSpace » Satellite-powered platform for carbon footprint insights

1.1 Taking care of our food's food

Every meal we plan, every bite of food we take, connects us to a complex, global network of farmers, manufacturers, traders, retailers, and countless other stakeholders. However, the challenges currently facing humanity are changing the ways in which we eat, as well as produce, our food.
Limited resources, shifting consumer behaviors, and technological advances have encouraged the adoption of new practices, allowing deep tech to slowly make an entrance into established traditions.

1.1.1 Why does it matter now?

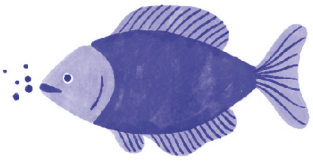
Agriculture is one of the oldest industries known to humankind, so it's no surprise that changes in its practices don't come easily. Bound by Earth's biological cycles and constraints, farmers everywhere depend on centuries-old methods to produce food for an ever-expanding population. Another factor that plays a big role: the spread of consumerism has put immense pressure on already-strained food systems. It is clear that current production practices are inadequate. The overuse of chemicals, increasing food waste, and ethical concerns in animal husbandry are just a few of the issues raised by the industry. Fortunately, recent years have provided crucial insight into the industry's outdated practices as well as the interconnectivity and circularity of our food systems. This new understanding is now shifting the way in which we view, consume, and also take care of our food.

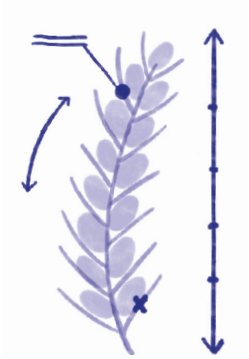
1.1.2 Applications and market potential

From animal husbandry to arable farming, new technologies are the surest bet for safeguarding our planet and its inhabitants. Because taking care of our food's food means taking care of ourselves, increasing both awareness and resources is essential to producing long-term benefits.

Novel animal feed

Most countries are catching up on livestock monitoring to reduce stress and disease. At the same time, pioneering technologies are already one step ahead, developing novelty feed, the largest and most important component for ensuring safe and adequate animal proteins. By leveraging synthetic biology and nanotechnology, the global feed market is expected to grow at a 4.2% CAGR from 2021 to 2025 [3] and will shake up practices from land to sea.





Precision agriculture

Leveraging data, robotics and automation, precision agriculture will forever change farming practices. With an outstanding 13.1% CAGR expected from 2021 to 2028 [4], global precision farming is on the verge of revolutionizing humankind's oldest industry. Technology-wise, the adoption of the Internet of Things (IoT) and the use of data science and advanced analytics by farmers have enabled the latter to (re) connect with their fields. Those who embraced precision agriculture in its early days can now go the extra mile and act on inputs. This newfound ability to understand, forecast, and nurture crops better than before means farmers worldwide can now increase their yields sustainably and gives industry leaders the chance to truly transform the world's oldest industry.

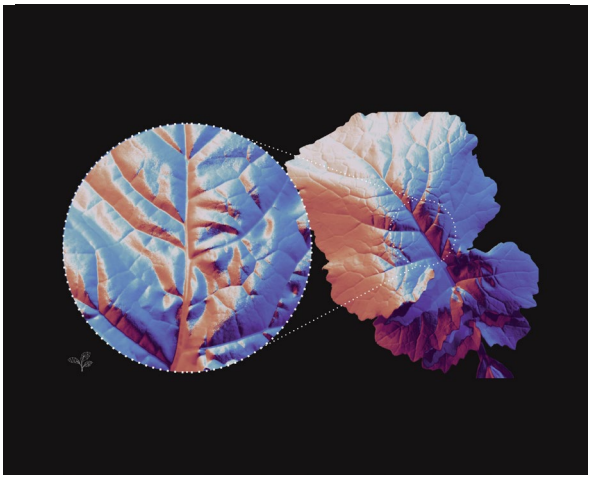
1.1.3 Key roadblocks to overcome

Adopting various new practices and products to nurture our food systems will depend on a balanced set of factors. Access to education and funding for farmers, as well as legislative guidelines, will be key. But it will also require a change in consumer habits worldwide. Additionally, farmers are understandably risk-averse as they might have to wait an entire year to plant a new crop should their experiments fail. To speed up deployment of these solutions, industry stakeholders and deep tech startups need to prove their investment rationale in a budget-constrained industry and focus efforts on experiments aimed at increasing ROI and lowering the risks perceived by farmers.

“Farmers worldwide can now increase their yields sustainably and give industry leaders the chance to truly transform the world’s oldest industry”

1.1.4 Use cases

BioFeyn » According to the FAO, global aquaculture production increased by 527% between 1990 and 2018. The rise in demand for fish protein can only be met with sustainable, healthy practices. **BioFeyn** has developed a specialized method to protect marine ingredients in feed pellets while also maximizing their nutritional quality, absorption, and nutrient bioavailability. The startup has multiple formulations in development and a pipeline of products to be released over the next five years.



Fotenix » Walking through kilometers of fields every day looking for signs of disease and stress visible to the human eye is part of a farmer’s daily routine. Using 3D spectral imaging, **Fotenix** proposes a device far more sensitive than the human eye to evaluate plant health in the field and save time. Able to detect stress and disease at a cellular level, the company enables optimized input application and timing, embracing precision agriculture.

LLEAF » With a 6.6% CAGR increase expected in the commercial greenhouse market from 2019 to 2026 [5], increasing yields' sustainably has become essential for indoor farming. The agricultural technology company **LLEAF** has invented a unique patented product that enables growers to harness the power of sunlight to increase yield and boost profits for farmers. The Luminescent Light-Emitting Agriculture Film (LLEAF) can be retrofitted onto greenhouse ceilings and possesses light-modifying properties.

Soil Carbon Co » Microbial carbon sequestration is one of the most important scientific endeavors of the 21st century. Selecting the right cohort of microbes, **Soil Carbon** has co-developed a microbial seed coating capable of removing CO2 from the atmosphere and storing it in the soil in a stable form. The company is tackling the challenges of restoring soil health and addressing climate change by optimizing a method well known to farmers, thereby bridging the gap between tradition and innovation.

1.1.5 What our startups need

Collaboration opportunities and constraints based on our deep tech pioneers' insights.

Experiment				Develop			Scale	
1	2	3	4	5	6	7	8	9
Exploration		Experimental, proof of concept		Functional proof of concept	Minimum viable product		Industrialization	Commercialization
				» Ensuring regulation approval » Finding talents to ensure proper development » Meeting biosecurity regulations with microbial transportation » Ensuring technology adoption by farmers » Confirming manufacturing capacities			» Ensuring proper pricing strategy for adoption » Protecting IP going forward	

1.2 From lab to fork: making cultured-everything a reality

According to a study published in the Science journal in 2018, meat and dairy account for 18% of all calories consumed by humans whereas their production uses 83% of global farmland, and produces 60% of agricultural greenhouse gas emissions[6]. The road ahead is paved with rising ethical concerns in farming and increasing pollution, the need to reduce land use for protein production, and a significant shift towards a plant-based diet for many consumers. In response, food scientists worldwide are now mobilizing to shape the future of food.

1.2.1 Why does it matter now?

The depletion of our agricultural resources calls for a change, one that will start in laboratories. Because while our crops are increasingly limited, our imagination and capabilities are not. With our extensive knowledge in medicine and tissue engineering, it was no surprise that the first food substitutes developed in laboratories were focused on conventional animal-based analogues. Now that excitement has plateaued and the first cultivated meat products have been approved for sale, it's time to scale.

1.2.2 Applications and market potential

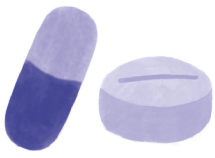
Increasing knowledge, capacities, and media attention have popularized alternative foods to an unprecedented level. Yet only new technologies capable of taking on this nearly $9 trillion industry [7] can tailor food to satisfy a global spectrum of diets.

Flavors

Apart from increasing production capacities using newly acquired knowledge and machinery, the general 'red meat-eating' public is still reluctant to adopt meat substitutes. Despite ticking every box in terms of shape, size, and texture, meat substitutes often lack a key component: a sufficiently meat-like flavor to satisfy connoisseurs. As a result, a handful of startups have bet on manufacturing fat cells to ensure the flavor component finds its way to new meat producers.

Venturing beyond alternative proteins

Deep tech startups worldwide have grasped the need to act and now offer solutions across the newly developed lab-to-fork value chain. Increasing capabilities in synthetic biology and nanotechnology are raising production levels to an all-time high and allowing scientists to venture outside of animal proteins, tapping into a broad spectrum of sources ranging from algae to cocoa beans, while industry processes are catching up in scaling capacities and production yields.



Personalized nutrition

The 'deconstruction' of food will pave the way towards isolated nutrients in diets and the emergence of personalized nutrition, an industry expected to top $3.3 billion by 2028 [8].

1.2.3 Key roadblocks to overcome

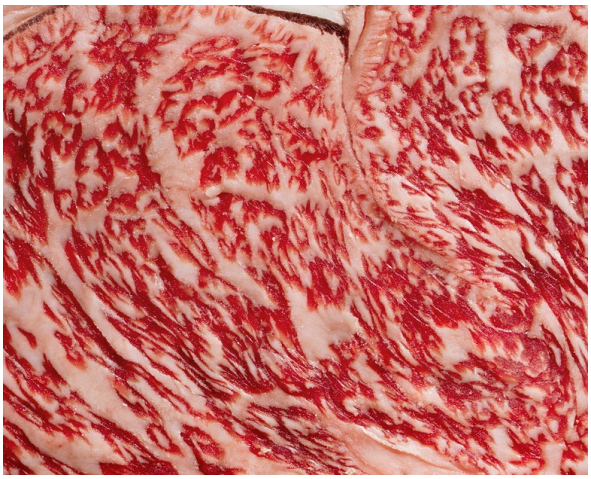
As these ultra-transformed foods get smarter, more accessible and tastier, consumers' reluctance to adopt is slowly diminishing. Nevertheless, the missing link in establishing the framework for this new normal will be regulatory. New policies and regulations will be key while funding, research capacities, and the education of future talents will help reduce production costs, and overall barriers to mass-scale adoption.

“Increasing capabilities in synthetic biology and nanotechnology are raising production levels to an all-time high”

1.2.4 Use cases

Cultured Decadence » Crustacean harvest relies on a carbon-intensive model and threatens both coastal waters and populations living off their bounty. Using in-house IP around cell isolation, tissue engineering, and media development, **Cultured Decadence** creates innovative methods to make crustacean products 1,000 miles from the nearest ocean. The startup aims to expand customer access to quality products, curb food waste, and reduce wild harvesting.

Cocuus System Iberica » Startups are taking 3D printing to the next level by joining the movement to create and use safe, reliable bioinks. Inspired by the morphological structure of various foods, **Cocuus System Iberica** uses 2D/3D laser printing, bioprinting, and robotics to produce plant-based and cell-based meat analogues, aka meat substitutes. Their Mimethica platform, using proprietary ingredients to formulate and produce printed animal protein, aims to manufacture up to 600kg of product per minute in the near future.



Hoxton Farms » Demand for alternative meat has grown by 125% in the last two years; however, the main roadblock to consumer adoption remains flavor. Tackling this next challenge in meat substitutes, **Hoxton Farms** uses mathematical modeling, machine learning, and synthetic biology to produce optimized cultivated fat. Leveraging the existing value chain, Hoxton Farms will sell customized cultivated fat as a B2B ingredient for the meat alternative market, allowing for the creation of all-new product classes.

California Cultured » Despite its expected market size of $61.3 billion by 2027 [9], cocoa production still involves slavery, deforestation, and poverty. Harnessing the latest advances in the field, **California Cultured** is producing cell-cultured chocolate food-grade upcycled media and high-value cocoa flavanols as an alternative. Secondary fermentation technology is in the works to add flavors and other attributes to their products, expected to range from health to cosmetic applications.

1.2.5 What our startups need

Collaboration opportunities and constraints based on our deep tech pioneers' insights.

Experiment				Develop			Scale	
1	2	3	4	5	6	7	8	9
Exploration		Experimental, proof of concept		Functional proof of concept	Minimum viable product		Industrialization	Commercialization

» Establishing proper definitions, regulation frameworks, and protocols

» Confirming support and funds despite the uncertainty of the technology

» Finding support and resources for prototyping

» Increasing manufacturing capacities to keep up with demand

1.3 Food systems as an agent of sustainability in the global supply chain

Spanning multiple continents to source and supply goods, the global supply chain involves a continuous flow of information, processes, and resources. As globalization and consumerism have increased, food systems have taken on a major role in the global supply chain, impacting it at every level. Developing its sustainability – and even resilience – is an ongoing trend and a necessity, one that has been accelerated by Covid-19 and the ensuing global disruption from which world commerce is still reeling.

1.3.1 Why does it matter now?

Identified as one of the most polluting sectors in the world, agriculture is nevertheless essential. Therefore, there is a real need to drive its transformation. Traditional food systems must find ways to achieve global climate and sustainability targets while remaining within planetary boundaries. Tapping into technologies from various industries, the entire sector can transform and pave the way towards real change.

1.3.2 Applications and market potential

The ability to adapt and be more resilient has become essential throughout the entire life cycle of food, from production to consumption to disposal. The good news is, there's no shortage of ways to achieve this. Our data show new technologies are focused on reducing fossil fuel-dependent energy, limiting waste, and monitoring agriculture's overall impact globally.

Waste reduction and upcycling

With one-third of global food production going to waste, it's no surprise that agricultural players have shifted their focus to limiting, if not eliminating, waste throughout the supply chain. Startups are making use of tools such as sensors, artificial intelligence, and machine learning to develop smart factories and processes. In addition, they have become more creative with the use of synthetic biology and nanotechnology to extend shelf life and can even anticipate product expiration through inspection and smart labels. Taking things one step further, new solutions in waste upcycling are challenging the status quo and creating value in discarded products.

Food traceability

Ensuring transparency involves greater strides in traceability and accountability. While blockchain and artificial intelligence are commonly used on the ground, satellite imagery borrowed from the aerospace industry offers a new perspective in monitoring impact on the global supply chain.

1.3.3 Key roadblocks to overcome

There are a myriad of ways in which societies must integrate sustainable food systems into the global supply chain. However, the obstacles to overcome can be narrowed down to a few. In a heavily regulated industry, commitments (both financial and regulatory) will be required to facilitate the transformation of food systems as well as a potential change in governance in land use. On an individual level, consumers everywhere will need to make dramatic changes in their habits and mentalities regarding food consumption and disposal. Real change is required regardless of geographic location.

“Tapping into technologies from various industries, the entire sector can transform and pave the way towards real change.”

1.3.4 Use cases

Crover » Grain storage accounts for the highest post-harvest losses before consumption as there is currently no way to verify the condition of grains in storage. Centered around the first proprietary technology for locomotion in bulk solids (i.e. sand, grains, powders), **Crover** has developed the world’s first ‘underground drone’ capable of propelling itself below the surface of dense granular media. Their first product is a probing device for the management of bulk-stored cereal grains like barley in sheds or silos enabling grain storage operators to identify critical conditions earlier and maintain grain quality.

GreenPod Labs » According to the FAO, one third, or 1.3 billion tons, of food produced for human consumption is lost or wasted globally every year. Indian startup **GreenPod Labs** uses active packaging sachets to trigger a defense mechanism that slows down ethylene production and activates microbe resistance. The resulting slowdown in the ripening rate and prevention of microbial growth help extend produce shelf-life and reduce overall waste.

Kosmode Health Singapore Pte Ltd
» Fiber-rich food processing waste streams can be upcycled into sustainable and economical function ingredients and food for humans. **Kosmode Health Singapore Pte Ltd** extracts bioactive ingredients from waste streams, customizes bioink formulation, and can produce new ingredients. This unique expertise enables the production of high-fiber and starch-free noodles as well as the printing of meat tissues.

CarbonSpace » Today, internal solutions for carbon footprint monitoring are costly, require manual labor, and are provided only annually. **CarbonSpace** has developed a satellite-powered platform that gives companies in the food and lumber industries insights into their carbon footprints. The monitoring tool brings a new level of transparency to supply chains via three modules: a monthly real-time map of greenhouse gas emissions, automatic estimation and verification of carbon footprints, and carbon analytics for impact estimation and emission reporting.

1.3.5 What our startups need

Collaboration opportunities and constraints based on our deep tech pioneers' insights.

Experiment				Develop			Scale	
1	2	3	4	5	6	7	8	9
Exploration		Experimental, proof of concept		Functional proof of concept	Minimum viable product		Industrialization	Commercialization
				» Funding the next steps » Testing marketing and value proposition strategies			» Ensuring on-site connectivity » Solid IP strategy and protection » Need for clear regulatory procedures and certifications » Efforts for scalability » Consumer acceptance for adoption	

Sources Report 1

1. FAO, 2015
2. Hello Tomorrow Global competition 2021
3. Technavio, 2021
4. Grand View Research, 2022
5. Knowledge Sourcing Intelligence LLP, 2021
6. Reducing food's environmental impacts through producers and consumers, Science, 2018
7. Statista, 2022
8. Grand View Research, 2021
9. Fortune Business Insights, 2020

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hello tomorrow

Hello Tomorrow is accelerating radical solutions to improve human and planetary health, leveraging the power of deep tech ventures. Its flagship startup competition, the Hello Tomorrow Global Challenge, received more than 25,000 applications from 132 countries. Thousands of corporates and VCs attend Hello Tomorrow events every year. Leveraging this international network and knowledge of deep tech trends, Hello Tomorrow partners with private and public organizations to help them identify new opportunities, and build new ventures to seize them.

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