

AGRICULTURE 4.0: THE FUTURE OF FARMING TECHNOLOGY

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WORLD GOVERNMENT SUMMIT



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INTRODUCTION

In 2015, the UN 2030 sustainable development agenda and international community committed itself to ending hunger (Transforming Our World: The 2030 Agenda for Sustainable Development). How close are we to reaching the objective? The short answer: Not close at all—roughly 800 million people worldwide suffer from hunger. And under a business-as-usual scenario, 8 percent of the world's population (or 650 million) will still be undernourished by 2030.

Although demand is continuously growing, by 2050 we will need to produce 70 percent more food. Meanwhile, agriculture's share of global GDP has shrunk to just 3 percent, one-third its contribution just decades ago. The reality is that very little innovation has taken place in the industry of late—in any case, nothing to indicate that food scarcity and hunger will not be an issue in the coming decades. The world needs drastic change: following the current path will not solve the problem.

Four main developments are placing pressure on the legacy agriculture model in meeting the demands of the future: demographics, scarcity of natural resources, climate change, and food waste are all intensifying the hunger and food scarcity problem.

To meet these challenges will require a concerted effort by governments, investors, and innovative agricultural technologies. It can be done, but we need to disrupt the system.

Agriculture 4.0 will no longer depend on applying water, fertilizers, and pesticides uniformly across entire fields. Instead, farmers will use the minimum quantities required and target very specific areas. It will be possible to grow crops in arid areas, making use of abundant and clean resources such as the sun and seawater. Other innovations—3D printing of foods, cultured meat, genetic modification, and seawater agriculture—are still in the early stages but could all be game changers in the next decade.

Farms and agricultural operations will have to be run very differently, primarily due to advancements in technology such as sensors, devices, machines, and information technology. Future agriculture will use sophisticated technologies such as robots, temperature and moisture sensors, aerial images, and GPS technology. These advanced devices and precision agriculture and robotic systems will allow farms to be more profitable, efficient, safe, and environmentally friendly.

These efforts will not come cheap: To end hunger by 2030 and accommodate the demographic pressure will amount to annual investments of US\$265 billion, according to an FAO report.

Governments can play a key part in solving the food scarcity issue. They need to take on a broader and more prominent role than their traditional regulatory and facilitating function. Our view is that in today's age of disruption, no one can act alone. A broader and international collaboration needs to be structured, while preserving the required agility to drive innovation. Governments can drive the setup of goal-oriented programs aimed at solving the food security dilemma. Those programs, however, cannot only follow the typical ecosystem and cluster approach in which governments enable the ecosystem and provide an environment for players to compete in. The culture of such programs (think: the Apollo moonshot program) require the setting up of international collaboration, building on public/private/R&D partnerships where funding is measured on problem-solving outcomes and based on attracting the best talent. The programs must be focused on creating new products, solutions, and market leaders. But doing this calls for governments stepping up to the plate and having a clear path towards this goal.

By challenging the traditional legacy model and pursuing such a program, governments can:

- Ensure food security and reduce dependency on imports
- Become a net exporter not only of products but also IP and new solutions
- Increase productivity and support the shift towards an innovation- and knowledge-based economy

Success will come to those who dare to dream in a world without hunger and food scarcity.

1. THE AGRICULTURE INDUSTRY IS FACING SEVERAL CHALLENGES

A number of global trends are influencing food security, poverty, and the overall sustainability of food and agricultural systems.

The four main developments placing pressure on agriculture to meeting the demands of the future: demographics, scarcity of natural resources, climate change, and food waste.

1.1. AN ELEVATED INCREASE IN DEMOGRAPHICS WILL BOOST DEMAND FOR FOOD

Population is growing: In the coming decades, world population is expected to grow to by 33 percent, to almost 10 billion by 2050, up from 7.6 billion (as of October 2017¹). By 2100, the global population is expected to reach 11.2 billion. That figure may understate actual fertility rates—under other scenarios, population could hit 16.5 billion.

Population growth will boost demand for food, even in a modest economic growth scenario, by roughly 50 percent as compared to 2013 agricultural output.

Meanwhile, the global diet is changing too, as a result of shifting demographics: There's a growing demand for high-value animal protein, a trend that (in addition to natural population growth) is being driven by urbanization and rising incomes.

Urbanization is increasing: Global urbanization between now and 2050 could lead to a net addition of 2.4 billion people to towns and cities. Urbanization stimulates improvements in infrastructure, such as cold chains, which permit trade in perishable goods.

It also tends to raise incomes, increasing demand for processed foods as well as animal-source food as part of a broader dietary transition. Annual per capita meat consumption is projected to reach 45.3 kilograms per person in 2030, up from 36.4 kg in 1997-1999².

But there's a downside to richer diets, especially the excessive consumption of meat. In developed nations, the lack of fresh foods, dependence on fast foods (many of them meat-based) and processed foods has led to a crisis in childhood obesity and to staggering numbers of people suffering from chronic diseases such as diabetes, high blood pressure, and heart conditions. Indeed, chronic disease makes up almost one-half of the world's burden of disease, creating a double burden when coupled with those infectious diseases that are still the major cause of illness in developing countries³.

Equally important are the effects of increased meat production on the environment: Raising livestock accounts for nearly one-fourth of all global water use in agriculture and is responsible for an estimated 18 percent of human-caused greenhouse gas emissions. In the long term, the impact on the environment is unsustainable.

Simply put: More people means greater demand and that demand in turn entails increased output. Farmers will have to produce 70 percent more food by 2050, according to the UN Food and Agriculture Organization (FAO). And this food will need to be customized to the needs of a growing urban population, a factor that encompasses the entire agriculture value chain.

Although agricultural investments and innovations are boosting productivity, yield growth has slowed to rates that are too low for comfort. Equally pressing is the question: Who will farm? Even as food needs and demand are increasing, the rural population is shrinking. Additionally, rural populations are rapidly aging, which has major implications for the workforce, production patterns, land tenure, social organization within rural communities, and economic development in general.

1. United Nations World Population Prospect 2017 [<https://esa.un.org/unpd/wpp/>].

2. World Health Organization [http://www.who.int/nutrition/topics/3_foodconsumption/en/index4.html]

3. <http://www.prb.org/Publications/Articles/2006/HealthCareChallengesforDevelopingCountrieswithAgingPopulations.aspx>

Exhibit 1: Demographics

**POPULATION
GROWTH =
HIGHER DEMAND
FOR FOOD**



10 billion

world population in 2050

=



70%

More food to be produced by farmers

**URBANIZATION
DRIVES CHANGE IN
CONSUMPTION
PATTERN**



36.4 kg

processed food and meat annual
per capita meat consumption
1997–1999

→



45.3 kg

processed food and meat annual
per capita meat consumption
2030

1.2. CURRENT USES OF NATURAL RESOURCES ARE HIGHLY STRESSED

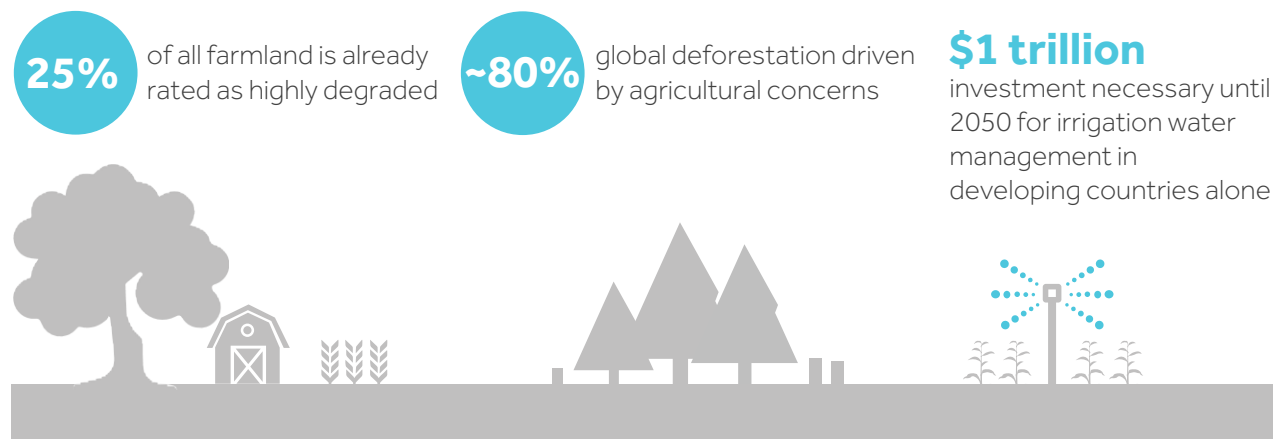
The world's farmland is becoming increasingly unsuitable for production: On the basis of certain metrics, 25 percent of all farmland is already rated as highly degraded, while another 44 percent is moderately or slightly degraded. Water resources are highly stressed, with more than 40 percent of the world's rural population living in water-scarce areas. Land has long been recognized as a finite resource, but in earlier times degraded farmland would simply be replaced by bringing new, unused land into cultivation. Such lands are rare nowadays, and what remains often cannot be farmed on a sustainable basis. Land shortage has resulted in smaller farms, lower production per person, and greater landlessness—all adding to rural poverty.

Agriculture is a primary cause—and indirect casualty—of farmland degradation, with different agricultural aspects contributing to this process in a variety of ways. Soil erosion is caused by overcutting of vegetation (clearing for farmland), along with improperly orchestrated fallow periods, crop rotations, and livestock overgrazing. Unbalanced fertilizer use to restore yield is leading to an imbalance in nutrients.

Approximately 80 percent of global deforestation is driven by agricultural concerns. And while clearing vegetation to make way for farmland does not directly produce soil degradation, and is necessary for land clearance, it does so indirectly by eroding water resources. This last point is worthy of note: Although irrigation systems have maximized usage efficiency, growing populations make water security and scarcity a real concern. The investment deemed necessary until 2050 is \$1 trillion for irrigation water management in developing countries alone.

All of these issues are the product of poor foresight and planning. Land shortage and poverty yield unsustainable land management practices, the direct causes of degradation named above. It is Poor farmers are led to clear forests, cultivate steep slopes without conservation, overgraze rangelands, and make unbalanced fertilizer applications. A projected investment of \$160 billion will be necessary for soil conservation and food control.

Exhibit 2: Natural Resources



DIRECT AND INDIRECT CAUSES OF DEGRADED FARMLAND

Degradation of farmland has many different causes, some of which are direct causes leading to the ruin of farmland, and others of which have contributed indirectly to a shrinking landscape. Among the direct causes are:

- **Deforestation of unsuitable land:** Deforestation is both a type of degradation as such, and also a cause of other kinds of despoliation, principally water erosion. Deforestation in itself is not degrading: It becomes a source of degradation when the land that is cleared is sloping, or has shallow erodible soils, and is followed by poor management.
- **Overcutting vegetation:** Rural people cut natural forests and woodlands to obtain timber, fuel, and other forest products. Overcutting has led to water erosion and wind erosion, resulting in land less suitable for food crops.
- **Inadequate fallow periods:** Shifting cultivation was a sustainable form of land use, at a time when low population densities allowed fallow periods. But shortened fallow periods have led to it becoming non-sustainable.
- **Overgrazing:** Overgrazing leads directly to decreases in the quantity and quality of the vegetation cover, which in turn lead to a decline in the soil's physical properties and resistance to erosion.
- **Improper crop rotation:** Due to economic pressures, farmers have adopted cereal-based, intensive crop rotations, in place of more balanced rotations.
- **Unbalanced fertilizer use:** Where soil fertility has declined, farmers attempt to maintain crop yields through fertilizer. But this has led to soil-nutrient imbalance.

1.3. CLIMATE CHANGE IS REDUCING PRODUCTIVITY IN AGRICULTURE

Climate change is a fact—and it is rapidly altering the environment. The degree of manmade emissions of greenhouse gases (GHGs) has reached the highest in history, according to a 2014 report of the Intergovernmental Panel on Climate Change (IPCC).

Agriculture is one of the primary producers of GHGs:

Over the past 50 years, greenhouse gas emissions resulting from agriculture, forestry, and other land use have nearly doubled. Agriculture contributes the largest share of global methane and nitrous oxide emissions. And projections suggest a further increase by 2050.

Reduced productivity in agriculture: A side effect of climate change is an increase in the variability of precipitation and a rise in the frequency of droughts

and floods, which tend to reduce crop yields. Although higher temperatures can improve crop growth, studies have documented that crop yields decline significantly when daytime temperatures exceed a certain crop-specific level (FAO, 2016e).

Climate change will affect every aspect of food production:

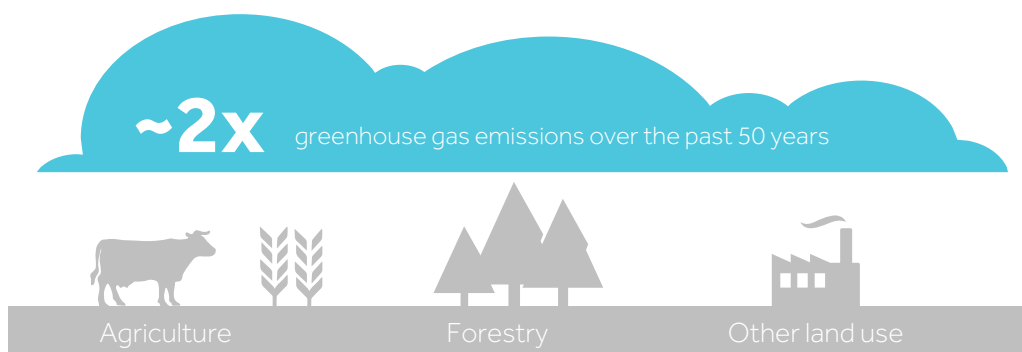
Increasing variability of precipitation and more droughts and floods is likely to reduce yields. Climate change will contribute to existing long-term environmental problems, such as groundwater depletion and soil degradation, which will affect food and agriculture production systems.

Without efforts to adapt to climate change, food insecurity will increase substantially:

Climate change's impact on global food security will relate not merely to food supply, but also food quality, food access, and utilization.

Exhibit 3: Climate Change

GREENHOUSE GAS EMISSIONS



VARIABILITY OF PRECIPITATION REDUCE CROP YIELDS



Rise in the frequency of droughts and floods, all of which tend to reduce crop yields

1.4. FOOD WASTE IS A MASSIVE MARKET INEFFICIENCY AND AN ENVIRONMENTAL THREAT

Between 33 percent to 50 percent of all foods produced globally is never eaten, and the value of this wasted food is more than \$1 trillion. To put that in perspective, US food waste represents 1.3 percent of total GDP. Food waste is a massive market inefficiency, the kind of which does not persist in other industries.

Meanwhile 800 million people go to bed hungry every night. Each and every one of them could be fed on less than a quarter of the food that is wasted in the US, UK, and Europe each year.

Because we have a globalized food supply system, demand for food in the West can drive up the price of food grown for export in developing countries, as well as displace crops needed to feed native populations.

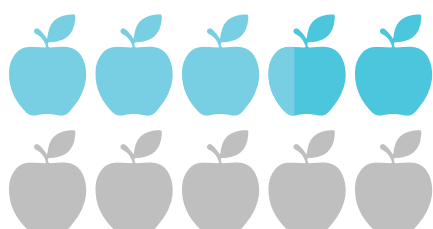
Moreover, hunger is not just a problem that's happening "somewhere else" – in the UK, for example, over 1 million people accessed a food bank last year, while in the US, 40 million Americans live in food poverty.

Food waste is bad for the environment, too. It takes a land mass larger than China to grow food that ultimately goes uneaten – land that has been deforested, species that have been driven to extinction, indigenous populations that have been moved, soil that has been degraded – all to produce food that is then just thrown away. In addition, food that is never eaten accounts for 25 percent of all fresh water consumption globally.

Not only are all of the resources that went into creating the uneaten food wasted (land, water, labor, energy, manufacturing, and packaging), but when food waste goes to the landfill, which is where the vast majority of it ends up, it decomposes without access to oxygen and creates methane, which is 23 times more deadly than carbon dioxide.

Every which way you look at it, food waste is a major culprit in destroying our planet: If food waste were a nation, it would be the third-largest emitter of greenhouse gases after China and the US.

Exhibit 4: Food Waste



between
33%-50% =
of all food produced
globally is never eaten



25%
of all fresh water
consumption globally



largest emitter of greenhouse gases after **China** and the **US**, if food waste were a country

1.5. OUTCOME: POVERTY AND HUNGER

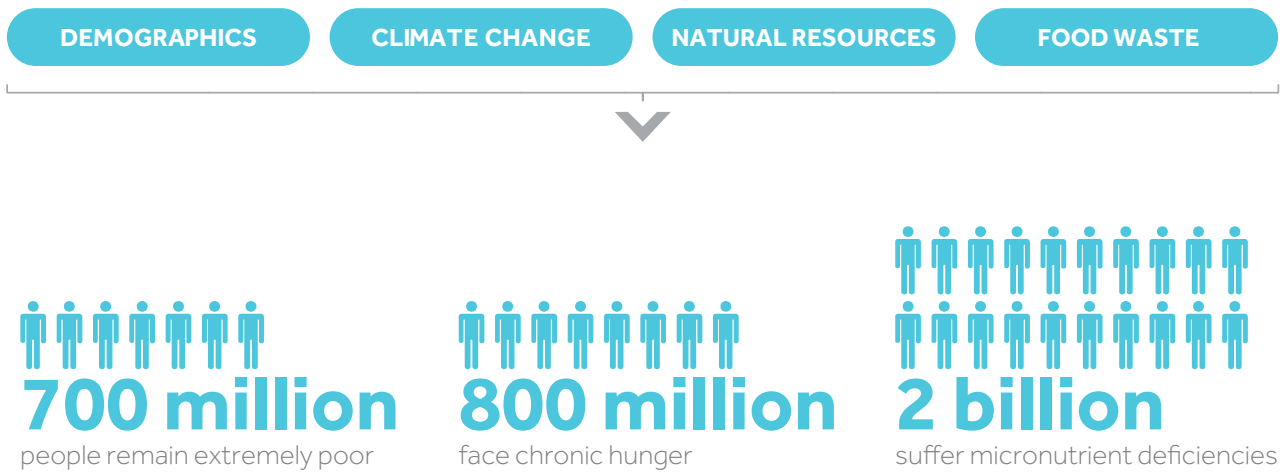
These macro trends have led to the food scarcity problem. The outcome has been poverty and hunger globally: 700 million people remain extremely poor, 800 million face chronic hunger, and 2 billion suffer micronutrient deficiencies. Of the 800 million, the World Bank estimates that one-third live in rural areas in developing countries. The overwhelming majority also live in countries driven by political crises and violent conflicts that undermine the social safety nets intended to help them.

To combat these trends, a number of avenues lie open. The food and agriculture industries have made

enormous strides in the past half-century: Green Revolution technologies have tripled global agricultural production since 1960, and the industry has become increasingly globalized. Eradicating world poverty and hunger will involve tapping those trends, as well as fighting income inequality. Growth strategies will be necessary that address not only agriculture but also job creation and income diversification.

One thing, however, is clear: Business as usual will not work. A Food and Agriculture Organization report has estimated that, globally, additional investments required to end hunger by that year would amount to US\$265 billion every year ⁴.

Exhibit 5: All the trends lead to scarcity and hunger



4. "The State of Food Insecurity in the World." (FAO, IFAD and WFP, 2015)

2. AGRICULTURE 4.0: DISRUPTING THE SYSTEM IS DOABLE WITH NEW TECHNOLOGIES

The traditional approach of the food industry is undergoing a fundamental transformation. The first technology revolution in agriculture made impressive strides: Between 1961 and 2004, cereal yields in East Asia rose by 2.8 percent a year, or over 300 percent over the period, enabled by modern farming practices, including irrigation, use of fertilizers and pesticides, and the development of new and more productive crop varieties (World Bank 2008⁵).

But efficiency gains are dropping: The rate of yield increases has slowed. And the challenges are greater: The world has to produce 70 percent more food by 2050, using less energy, fertilizer, and pesticide while lowering levels of GHGs and coping with climate change. Old technologies must be maximized, and new ones generated.

Agriculture 4.0, the coming agricultural revolution, must be a green one, with science and technology at its heart⁶. Agriculture 4.0 will need to look at both the demand side and the value chain/supply side of the food-scarcity equation, using technology not simply for the sake of innovation but to improve and address the real needs of consumers and reengineer the value chain.

Modern farms and agricultural operations will work differently, primarily because of advancements in technology, including sensors, devices, machines, and information technology. Future agriculture will use sophisticated technologies such as robots, temperature and moisture sensors, aerial images, and GPS technology, to list a few. These advances will let businesses be more profitable, efficient, safer, and environmentally friendly.

Agriculture 4.0 will no longer have to depend on applying water, fertilizers, and pesticides across entire fields. Instead, farmers will use the minimum quantities, or even completely remove them from the supply chain. They will be able to grow crops in arid areas and use abundant and clean resources such as the sun and seawater to grow food.

The good news is that these digital and technological advancements are taking over the industry, enhancing the entire food value chain. Agricultural technology startups, according to Agfunder, have grown more than 80 percent per year since 2012. Agritech startups are booming, with entrepreneurs and investors showing a voracious appetite for the sector: Business leaders Bill Gates, Richard Branson, and Jack and Suzy Welch, along with the VC fund DFJ (known for its investments in Tesla and Twitter) and the food conglomerate Cargill, have invested in Memphis Meats, a pioneering clean-meat company. And SoftBank Vision Fund, under the direction of Japanese billionaire Masayoshi Son, is pouring \$200 million into the vertical indoor farming startup Plenty; other participants in the round of funding in Plenty included Amazon's Jeff Bezos and tech billionaire Eric Schmidt.

So, what are the new technologies and solutions in the Agriculture 4.0 that can give hope to the food scarcity problem? We see three general trends where technology is disrupting the industry that we will address, showing specific examples of solutions with high potential to disrupt the system:

1. Produce differently using new techniques
2. Use new technologies to bring food production to consumers, increasing efficiencies in the food chain
3. Incorporate cross-industry technologies and applications

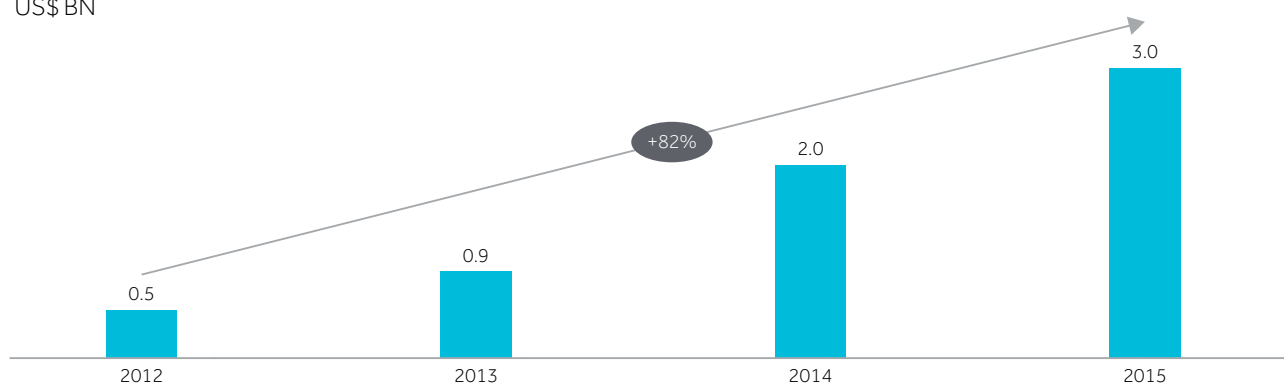
5. World Bank 2008 Annual world development report New York, NY: World Bank

6. "Food security: contributions from science to a new and greener revolution," by John Beddington.

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Exhibit 6: Investments in Agtech

GLOBAL VC INVESTMENTS IN AGTECH 2010-2015
US\$ BN



Source: Agtech, World Bank

RECENT NEWS

Bloomberg NEWS

SoftBank Vision Fund
Lead \$200 Million Bet on
Indoor Farms

The SoftBank Group Corp. chief's Vision Fund is leading a \$200 million investment in Silicon Valley startup Plenty, which says it has cracked the code on growing crops indoors super efficiently.

Bloomberg Technology

Bill Gates and Richard Branson Back Startup That Grows "Clean Meat"

IKEA, David Chang and the ruler of Dubai invest \$40 million in AeroFarms vertical farming

KKR invests \$100 million in arid climate agriculture firm

Reuters, 2014
<https://www.reuters.com/article/kkr-sundrop/kkr-in-vests-100-million-in-arid-climate-agriculture-firm-idUSL3N0TO07R20141204>

2.1. PRODUCE DIFFERENTLY USING NEW TECHNIQUES



HYDROPONICS

Hydroponics, a subset of hydroculture, is the method of growing plants without soil, using mineral nutrient solutions in a water solvent.

Sundrop, for example, a company based in Australia, has developed a hydroponics seawater technology that combines solar, desalination, and agriculture to grow vegetables in any region. This system is sustainable, doesn't rely on fossil fuels (drawing its energy from the sun instead), and doesn't require land. Instead, its technologies integrate solar power, electricity generation, freshwater production, and hydroponics. The result: an equivalent quantity of food to that

grown using traditional methods. By using hydroponics, Sundrop can put a seawater greenhouse—a combination of solar, desalination, and agriculture—to grow vegetables anywhere in the world.

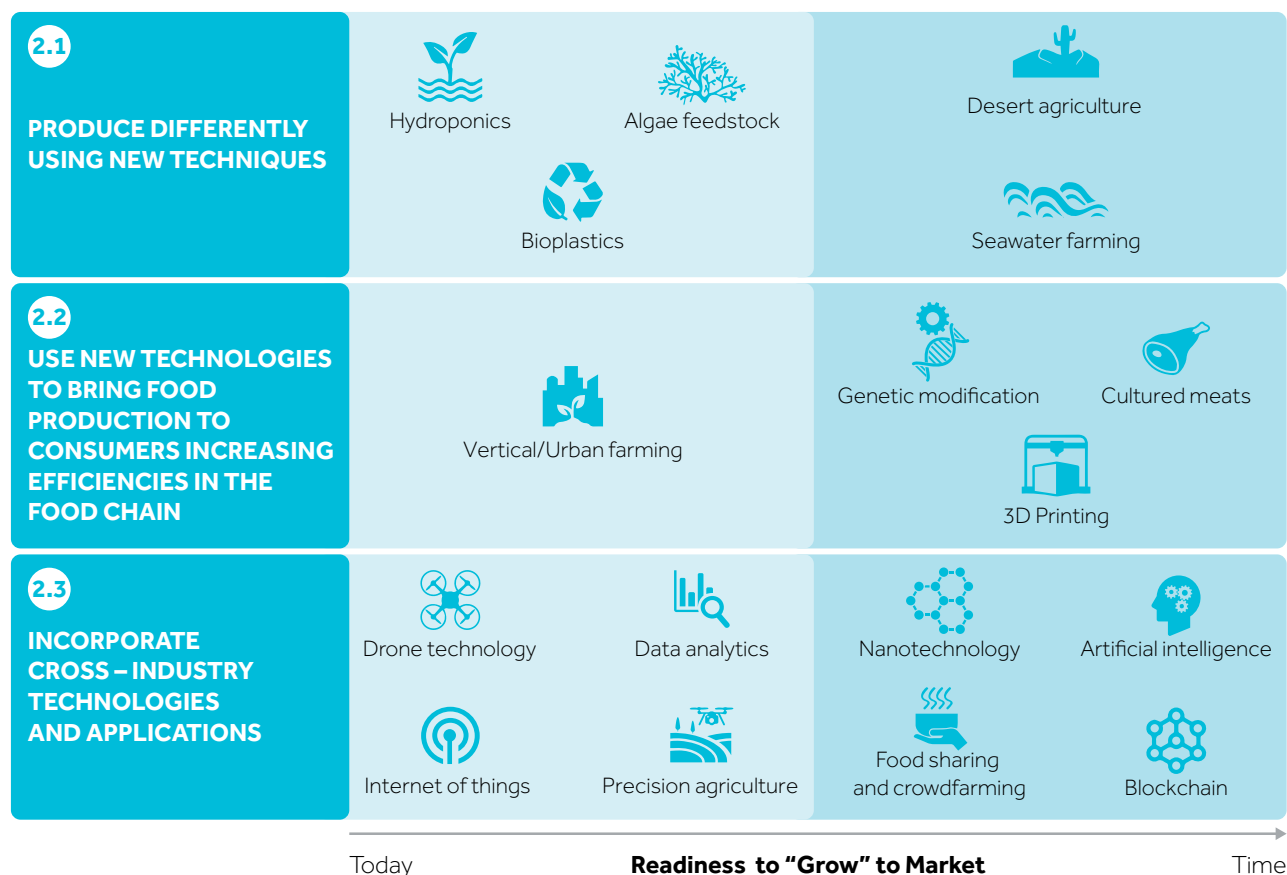


ALGAE FEEDSTOCK

Algae farmed in aquaculture sites can become a substitute for feedstock and fishmeal. The cost of farming algae in most locations is between \$400 and \$600 per metric ton, a 60 percent to 70 percent savings compared to fishmeal, which costs \$1,700 per ton. Plus, algae is a more reliable source of feedstock, given that its availability is not dependent on catching fish. This provides producers greater control over costs and the ability to forecast future investment or financial results thanks to the reduction of risk in aquaculture farming operations.

Exhibit 7: Time of adoption

MAP OF TECHNOLOGIES AND MATURITY



Fisheries are the most important sources of feedstock. However, only a small percentage of global fish production is actually channeled towards human consumption, with the rest used for fish feed and animal feed. The proportion of fish processed into fishmeal is unlikely to grow due to increasing demand for fish products in emerging economies such as China. And there are doubts as to whether the world's catch can be increased in a sustainable way.

The same holds true for animal feedstock, especially cattle, which are the least efficient links in food production. The conversion rate is 15 percent or lower, meaning that you need to feed cattle 1 kg of feed to get 150 grams of meat. Algae-based feedstock is an effective and inexpensive substitute.

DESERT AGRICULTURE AND SEAWATER FARMING

Most of the world's surface is covered in water, in the form of oceans. The remaining landmass of the Earth amounts to approximately 29 percent of the surface. Of this remaining 29 percent,

one-third consists of deserts of all types. To tackle the food crisis, the world must turn the world's desert and sea into food production facilities, an effort that will need the combined brainpower of the brightest minds, universities, and research facilities.

The King Abdullah University for Science and Technology (KAUST) in Saudi Arabia is at the forefront of research on desert agriculture: The Desert Agriculture Initiative at KAUST seeks to tackle the wider suite of difficult challenges posed by agriculture in a desert environment. KAUST is working on both biotic and abiotic factors. Key areas of biotic research include: Genome engineering technologies to manipulate biological systems and plant growth and development; growth regulators that improve plants or response to adverse conditions; and plant hormones that shape shoot and root architecture according to nutrient availability.

Given that harvest losses by drought, salt, and heat amount to approximately 60 percent of total productivity, improving abiotic stress tolerance is key to crop improvement. The ability of plants to adapt to extreme stress conditions depends on the association with specific microbes. KAUST is seeking to: identify microbes associated with plants growing in extreme heat, drought, and salt conditions; identify the molecular mechanisms that enable plants to adapt to extreme environmental conditions induced by the microbial association; and use the appropriate rhizosphere partners to enhance plant stress tolerance and help increase crop food production in a sustainable way.

Finally, KAUST is also working to breed crops with enhanced stress tolerance by learning whether improved pathogen resistance, stress tolerance, and yield are dependent on somatic memory and whether modification of chromatin factors can contribute to future stress tolerance.



SUSTAINABLE PACKAGING: BIOPLASTICS

New technologies and solutions are disrupting not only the production side of the value chain but also food packaging. And it's long overdue, what with 100 million tons of debris drifting in the oceans, much of it disposable plastic-food packaging containers and bags. Consumers increasingly are urging companies to develop food containers that can be recycled and are biodegradable or compostable too.

Bioplastics have been around for more than 20 years. However, they haven't managed to deliver on the promise of bringing the same packaging usefulness as plastic and returning 100 percent back to nature, with no harmful impact. The startup TIPA, however, wants to change all that.

TIPA was founded to create viable plastic packaging solutions. Its vision is to create a compostable, recyclable package that is the equivalent to a fruit or vegetable: something that when discarded, would decompose and leave no toxic residue.

TIPA is developing an advanced flexible plastic packaging that fits seamlessly into current food manufacturing processes, offers consumers and brands the same durability and shelf life they have come to expect of ordinary plastics, but that can return to nature after it has been used, much like an orange peel becomes part of the food waste stream.

2.2. USE NEW TECHNOLOGIES TO BRING FOOD PRODUCTION TO CONSUMERS, INCREASING EFFICIENCIES IN THE FOOD CHAIN



VERTICAL AND URBAN FARMING

In 2016, the UAE imported over four million metric tons of fruits and vegetables. Facilitating the growth of a cost effective, commercial-scale agribusiness that provides fresh produce to local populations will deliver benefits to both the UAE government and its citizens.

Vertical farming is one answer to providing high-quality produce sustainably. Vertical farming is the process of growing food in vertically stacked layers, producing food in challenging environments where suitable land is unavailable. Associated with urban farming, it uses soil, hydroponic, or aeroponic growing methods. The process uses 95 percent less water, less fertilizer and nutritional supplements, and no pesticides, while boosting productivity.

Since 2004, US-based AeroFarms has been building, owning, and operating indoor-vertical farms that grow safe and nutritious food. It leads the world in high-tech, data-driven, commercial-scale vertical farming. Its farms can grow produce year-round, allowing it to reach potential yields that are 390 times more productive, than a traditional farm of the same acreage. Production is independent of extreme weather events or seasonal change. Because products are locally grown and not imported, fruits and vegetables stay fresher for longer.

Similarly, San Francisco-based Plenty's field-scale indoor farms combine agriculture and crop science with machine learning, IoT, big data, and climate-control technology, enabling it to grow healthy food while minimizing water and energy usage. Plenty recently fielded investments from SoftBank Vision Fund and Amazon CEO Jeff Bezos, which will help the company advance its farms.

Governments have also initiated initiatives around this technology. These growing techniques have fostered an indoor growing boom in the Netherlands: Greenhouses now produce 35 percent of the country's vegetables – despite occupying less than 1 percent of its farmland.

The Netherlands' Wageningen University has led much of the research on how to best grow crops indoors. But the Dutch agricultural revolution needs to move beyond greenhouses, which still rely on some outside forces like sunlight, according to Leo Marcelis, a professor at the university.

To be cost effective, however, vertical farming is dependent on affordable electricity. Governments can support the development of these farms by offering power subsidies or other tax incentives. Countries with a highly educated population, low energy costs, and a government willing to engage in public-private partnerships will ultimately become leaders in this space.



GENETIC MODIFICATION AND CULTURED MEATS

Crop improvement through conventional breeding techniques was employed in developing drought-resistant wheat, which led the first wave of improved yields in the developing world. But to address the food needs of the future, genetic engineering is needed.

Clustered, regularly interspaced, short palindromic repeat (CRISPR) technology is an important new approach to genome editing that allows greater selectivity and reduces the element of chance. The technique not only can create breeds with improved yields and resistance to adverse conditions, but can also be used to propagate crops with essential vitamins, nutrients, and minerals. CRISPR is facilitating the generation of engineered animal food products.

Culturing meat is a cutting-edge technology that has a lot of potential but is still in a fragile state of development. This technology has enormous potential to have an impact on the areas of food security, the environment, animal-borne food-related diseases, and animal welfare issues. MosaMeat, a Netherlands-based company, is among the handful of startups using the technology. MosaMeat is currently working

on developing cultured ground meat (hamburger) product, which it plans to bring to market in the next few years. The company believes lab-made meat—"meat without the butcher"—can provide the world's growing population high-quality protein while avoiding many of the environmental and animal-rights issues of conventional meat production.



APPLYING 3D PRINTING TECHNOLOGY TO FOOD

3D printing, which is becoming important in manufacturing industries, is now being applied food production. 3D printing (also known as additive manufacturing) is a process whereby layers of material are formed to create objects—and in this case, familiar dishes. Experts believe printers using hydrocolloids (substances that form gels with water) could be used to replace the base ingredients of foods with renewables like algae, duckweed, and grass.

Netherlands Organization for Applied Scientific Research has developed a printing method for microalgae, a natural source of protein, carbohydrates, pigments, and antioxidants, and is turning those ingredients into edible foods like carrots. The technology essentially turns "mush" into meals. In one study, researchers added milled mealworm to a shortbread cookie recipe.

Grocery stores of the future may stock "food cartridges" that last years on end rather than perishable whole ingredients, freeing up shelf space and reducing transportation and storage requirements.

The most exciting — and technically demanding — application for 3D food printers may be meat substitutes. Some researchers have begun experimenting with algae as a replacement for animal protein, while others are trying to make meat from cow cells grown in a lab.

2.3. INCORPORATE CROSS-INDUSTRY TECHNOLOGIES AND APPLICATIONS

Efficiency and productivity will increase in the coming years as “precision agriculture” becomes bigger and farms become more connected. It's estimated that by 2020, over 75 million agricultural IoT devices will be in use: The average farm will generate 4.1 million data points daily in 2050, up from 190,000 in 2014.

But while the growing number of connected devices represents a big opportunity for food producers, it also adds complexity. The solution lies in making use of cognitive technologies that help understand, learn, reason, interact, and increase efficiency. Some technologies are further along than others. But the innovations hold great promise. Here are some key game changers⁷:

- **Internet of Things (IoT):** Digital transformation is disrupting the agricultural world. IoT technologies allow correlations of structured and unstructured data to provide insights into food production. IoT platforms such as IBM's Watson are applying machine learning to sensor or drone data, transforming management systems into real AI systems.
- **Automation of skills and workforce:** By the 2050, the UN projects⁸ that two-thirds of the world's population will live in urban areas, reducing the rural workforce. New technologies will be needed to ease the workload on farmers: Operations will be done remotely, processes will be automated, risks will be identified, and issues solved. In the future, a farmer's skills will increasingly be a mix of technology and biology skills rather than pure agricultural.
- **Data-driven farming:** By analyzing and correlating information about weather, types of seeds, soil quality, probability of diseases, historical data, marketplace trends, and prices, farmers will make more informed decisions.
- **Chatbots:** Currently, AI-powered chatbots (virtual assistants) are used in retail, travel, media, and insurance sectors. But agriculture could also leverage this technology by assisting farmers with answers and recommendations on specific problems.



DRONE TECHNOLOGY

Drones aren't a new technology. But thanks to investment and a relaxed regulatory environment, their time may have arrived:

The value of drone-powered solutions in all applicable industries could be more than \$127 billion, according to reports⁹. And one of the most promising areas is agriculture, where drones have the potential to address major challenges¹⁰.

Drone technology is giving agriculture a high-tech makeover. Here are six ways drones will be used throughout the crop cycle:

- **Soil and field analysis:** By producing precise 3-D maps for early soil analysis, drones can play a role in planning seed planting and gathering data for managing irrigation and nitrogen levels.
- **Planting:** Startups have created drone-planting systems that decrease planting costs by 85 percent. These systems shoot pods with seeds and nutrients into the soil, providing all the nutrients necessary for growing crops.
- **Crop spraying:** Drones can scan the ground, spraying in real time for even coverage. The result: aerial spraying is five times faster with drones than traditional machinery.
- **Crop monitoring:** Inefficient crop monitoring is a huge obstacle. With drones, time-series animations can show the development of a crop and reveal production inefficiencies, enabling better management.
- **Irrigation:** Sensor drones can identify which parts of a field are dry or need improvement.
- **Health assessment:** By scanning a crop using both visible and near-infrared light, drone-carried devices can help track changes in plants and indicate their health—and alert farmers to disease.

UAVs may one day consist of autonomous swarms of drones, collecting data and performing tasks. The biggest obstacle to that becoming a reality is sensors capable of collecting high-quality data and number-crunching software that can make that high-tech dream a reality.

7. IBM: "Five Ways Agriculture Can Benefit from Artificial Intelligence."

<https://www.ibm.com/blogs/watson/2016/12/five-ways-agriculture-benefit-artificial-intelligence/>

8. UN World Urbanization Prospects report. <https://esa.un.org/unpd/wup/Publications/Files/WUP2014-Highlights.pdf>

9. <http://www.businessinsider.com/drones-telecommunication-industry-2016-9>

10. In Commercial Drone, the Race Is On, Oliver Wyman (2015)

http://www.oliverwyman.com/content/dam/oliverwyman/global/en/2015/apr/Commercial_Drones.pdf



BLOCKCHAIN AND SECURING THE AGRICULTURE VALUE CHAIN

Blockchain, the distributed ledger technology behind Bitcoin and other cryptocurrencies, allows for highly secure digital transactions and recordkeeping. While blockchain has mainly been used in virtual currencies, it can also be applied to other types of transactions, including agricultural ones.

Blockchain can reduce inefficiencies and fraud and improve food safety, farmer pay, and transaction times. By improving traceability in supply chains, it can enable regulators to quickly identify the source of contaminated foods and determine the scope of affected products during contamination incidents. Additionally, the technology can reduce waste by detecting bottlenecks in the supply chain contributing to food spoilage.

The transparency of blockchain can also help fight food fraud. As consumer demand for organic, GMO- and antibiotic-free food soars, the news is rife with cases of fraudulent labeling. The smallest transactions—whether at the farm, warehouse, or factory—can be monitored efficiently and communicated across the entire supply chain when paired with IoT technologies, such as sensors and RFID tags. Maersk, a shipping and logistics company, has intra-continent supply chains that involve dozens of personnel and hundreds of interactions. They estimate that blockchain could save them billions by improving efficiencies that reduce fraud and human error.

The benefits of openness extend to all honest market participants. Blockchain technologies can prevent price extortion and delayed payments while simultaneously eliminating middlemen and lowering transaction fees, leading to fairer pricing and helping smallholder farmers capture a larger part of their crop value.



NANOTECHNOLOGY AND PRECISION AGRICULTURE

The Green Revolution of the 20th century was driven by a blind use of pesticides and chemical fertilizers, resulting in a loss of soil biodiversity and a rise in resistance against pathogens and pests.

The new revolution will be precision agriculture, driven by nanotechnology¹¹. This revolution will see nanoparticles delivered to plants and advanced biosensors for precision farming. Nanoencapsulated conventional fertilizers, pesticides, and herbicides will release of nutrients and agrochemicals in a slow and sustained manner, resulting in precise dosage to the plants.

Among the benefits of nanotechnology precision farming are:

- Roughly 60 percent of applied fertilizers are lost to the environment, causing pollution
- Nanofertilizers helps in the slow, sustained release of agrochemicals, resulting in precise dosages
- Greater plant protection and treatment of diseases
- Biosensors can detect pesticides in crops, leading to more-informed decisions



FOOD SHARING AND CROWDFARMING

Finally the sharing economy and crowdsourcing also have a place in preventing food waste.

Technology has enabled communities to share their goods and services. This first became popular in ride sharing and house sharing, and now it is being applied to every industry, including food.

Olio, founded by social entrepreneurs, has built an app connecting people with their neighbors and local shops so that surplus food can be shared, rather than be discarded.

Another social entrepreneurial project, Naranjas del Carmen, has developed the concept of Crowdfarming. Naranjas del Carmen has created a system in which the person has ownership over the trees and land that the farmer cultivates. In this way, the fruit of those trees goes to their owners, creating a direct link between production and consumption and avoiding overproduction and waste along the value chain.

11. Nanotechnology: The new perspective in precision agriculture
By J.S. Duhan et al <http://www.sciencedirect.com/science/article/pii/S2215017X16301400>

3. THE ROLE OF GOVERNMENT

All these new technologies are changing the way stakeholders, and government in particular, think about the agriculture industry, giving hope to solving the hunger and food scarcity problem.

The role of government is one that cannot be overstated. We believe that as governments face the growing threat of climate change, natural resources shortages, and population pressure, they will increasingly need to step up to the plate and foster the technologies that make up Agriculture 4.0.

This transformation offers a great opportunity for government to take a leading position in the Agriculture 4.0 era.

By challenging the legacy model, governments can:

- Ensure food security and reduce dependency on imports
- Become a net exporter not only of products but also IP and new solutions
- Increase productivity and support the shift towards an innovation and knowledge based economy

In our view, there are two possible policy playbooks for government: the traditional industry approach of acting simply as a promoter and facilitator, or, a more targeted goal-oriented effort. We'll take a look at each one—but certainly doing nothing and keeping to the current scenario is not an option.

3.1. TRADITIONAL INDUSTRY PROMOTER/FACILITATOR APPROACH IS NOT ENOUGH: FOLLOW A TARGETED GOAL-ORIENTED APPROACH

In a traditional industry promotion-and-facilitator approach, government acts as an enabler of an ecosystem with targeted initiatives, creating a positive environment for players to participate in.

This is the more typical scenario for governments to attract industry players: it's an organic method, less dependent on a single charismatic visionary.

Under this scenario, governments lend support through:

- Partnerships to access new markets and commercialization support
- Financial incentives
- Regulatory flexibility
- Providing infrastructure at an affordable price

This approach, although it has more direct applications and is easier to implement in the short term, is also less likely to provide control over the types of players attracted. It is essentially a "build it and they will come" approach rather than a selective one where you ensure that the best and brightest are working together towards solving the problem.

It is also targeted towards commercial applications that have commercial players, and does not usually cover a broader collaboration of entities, universities, and other government programs.

Finally, the traditional industry promotion-and-facilitator approach is built around competition of countries for the best ecosystem.

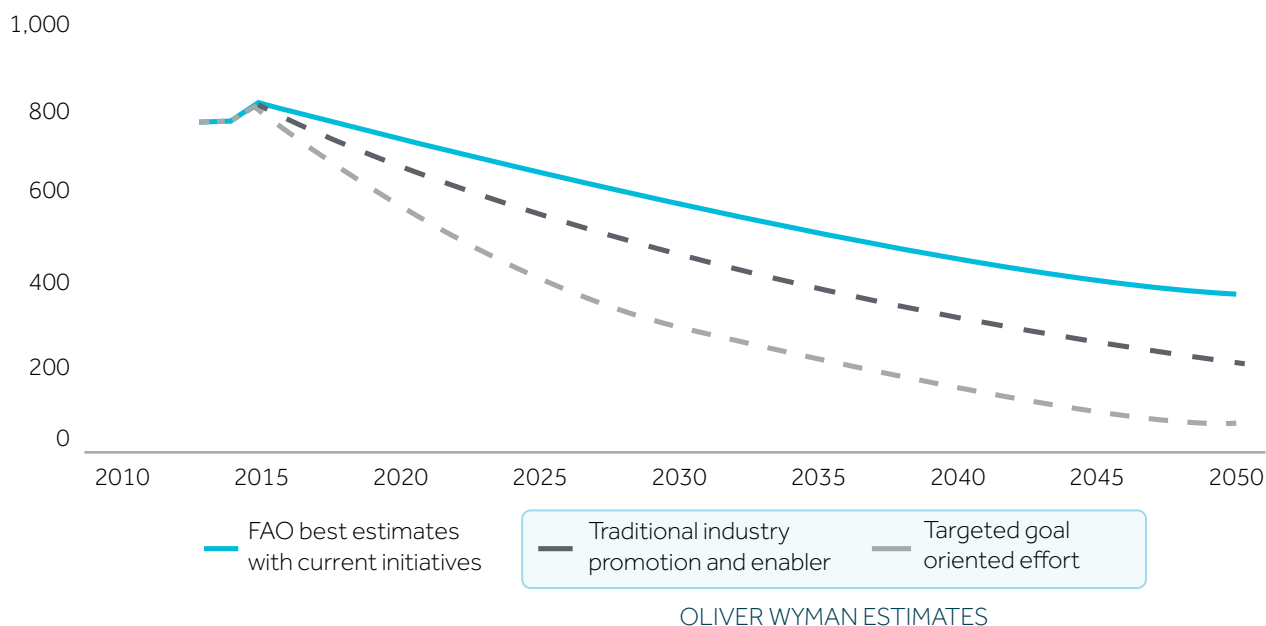
Under the targeted goal-oriented effort, nations regard the global food crisis not simply as a threat but as an opportunity. It allows them to seize the day and approach it as a "moonshot" program: tackling food scarcity the way the US tackled the challenge of the space race.

Targeted goal-oriented scenarios, however, usually require visionaries determined to bring about change. Such visionaries are rare. The best example of a successful, targeted effort is the Apollo Project, initiated by US President John F. Kennedy.

The moon landing in 1969 has been called the greatest technological achievement in human history. But when President Kennedy announced, in 1961, the goal of sending an American safely to the moon before the end of the decade, the chances of success were not deemed great: The US had yet to send a man into orbit, much less the moon. Indeed, the NASA officials tasked with reaching the objective questioned whether it could be done.

Exhibit 8: S curve of impact to achieve security – 1. doing nothing, 2. bottom up, 3. extreme program approach

SCENARIOS OF POPULATION LIVING IN HUNGER SITUATION
MM PEOPLE



But in 1969, eight years and \$24 billion later (or \$150 billion in current dollars), more than 500 million people watched from earth, on their television sets, as Neil Armstrong set foot on the moon. The Apollo mission built upon innovations in semiconductors, telecommunication, and automation, and expanded those technologies in ways that were unimaginable then. Those same technologies would later make possible globalization, outsourcing, lean manufacturing, and create our current global production systems, products, and mass customization.

Here are some lessons¹² from the first moonshot program:

- **Channel energies.** When Kennedy set the initiative in motion, he wasn't charting a new path; he was channeling existing capabilities. To create programs that work, don't start from scratch. Give direction, ambition, and urgency to initiatives in place.
- **Don't be prescriptive.** In setting the goal, Kennedy outlined concrete terms and gave a deadline. He left it to NASA to achieve the goal. To create programs that work, set out the what, the when, and leave the how to the experts.
- **Partner with others.** Although NASA had a team of some of the best engineers in the world, 12,000 corporations were involved in making the moon project happen. Get the best possible expertise from outside to add to your own.

- **Take small steps.** The best programs string together smaller projects in the service of the vision. NASA's program was a series of 23 small-scale, missions, each with its own teams and goals. This let NASA measure outcomes along the way.
- **Get return on your investment as you go.** Each mission served to underscore US superiority over the Soviets in space, effectively giving the US a return on its investment. Develop programs so that the returns don't pay out only at the end.
- **Communicate progress.** Tell your story well to the people who matter most.

THINK BIG

The concept of moonshot program technologies calls for thinking big and executing even bigger, rather than remaining stuck with only incremental advances. But these programs are high cost and high risk: They require enormous human efforts and expenditures to turn them into a reality. Are they the domain of only the truly gifted visionary, one who comes along perhaps once in a generation? Or is it possible for other governments and leaders to tap into the formula for unlocking groundbreaking innovation and change?

12. "What Your Moonshot Can Learn from the Apollo Program," by John Geraci (Harvard Business Review).

Exhibit 9: Differences of approaches

POSSIBLE SCENARIOS

TRADITIONAL INDUSTRY PROMOTION AND ENABLER BOTTOM-UP APPROACH		TARGETED GOAL-ORIENTED EFFORT TOP-DOWN APPROACH	
Supply Focus – build it and they will come		Demand focus make them come first and then build with them	
Organic – pulled		Planned growth – pushed	
Competitive – build on anchors and suppliers relationship		Collaborative – build on P/P/R&D partnership	
Location focus/global competitiveness		Goal focus	
Incentives based to gain scale		Problem-solving funding based to attract best partner	
Localizing existing industry/value chain/ displacing competition		Shaping future solution and new products/create new champions	
Broad and diverse		Focused and targeted	

While technology is certainly part of the solution, it alone cannot solve the global hunger and food crisis. To solve the coming crisis, governments and leaders must demonstrate the kind of vision and courage shown by Kennedy.

And government must take a primary not secondary role: Government needs to be fully engaged, working to enable and foster a full ecosystem of technology companies, research centers, universities, and innovative startups working together to create a common solution for addressing the demand/food scarcity problem that the world faces.

PROGRAMS ARE NOT AN EITHER/ OR PROPOSITION

The food crisis calls for bold solutions. We need moonshot programs—but we need ones that work. Making that happen should not be impossible. It should be a matter of understanding the correct steps to take and following through.

In our view, governments need not take an either/or stance towards targeted goal oriented effort versus traditional and targeted approach. Governments ought to adopt a goal-oriented and problem-solving mentality, based on collaboration across different entities to disrupt the value chain; at the same time, however, they should use specific enablers and steps to create an environment to turn this into a reality—and then be prepared to activate it with ready-to-go short-term projects. Yes, we need an extreme solution—but we need it now.

WHAT SHOULD GOVERNMENTS BE DOING?

Governments should improve the ecosystem and enable the environment. Offer financial incentives, regulatory flexibility, and provide infrastructure at an affordable price.

Governments need to be at the forefront of the addressing the food security issue. They must enable progress through judicious incentives and smart regulation. Doing that means taking the lessons learned from earlier successful government moonshot programs like the Apollo Space Mission and applying them to ending food scarcity. It also means defining the objectives clearly—but at the same time leaving the details to the innovators and the people on the ground. Several steps can be considered in this direction:

- Harmonize food-safety systems
- Increase in-process transparency of quality
- Develop a national center of excellence in food-safety research and collaboration
- Investigate and consider the impacts of non-tariff barriers to trade
- Enhance domestic food testing capabilities

Governments can play a key role in fostering collaboration, which is essential for achieving scale, efficiency, and agility across changing value chains and markets—particularly where the domestic market is small and industry consists of relatively small businesses.

To be competitive, businesses need to be able to access information and expand their approach to include knowledge and resource sharing with local competitors and international peers. Critical to this effort is the depth and quality of networks and interactions. Deep networks allow for faster, more innovative solutions.

Improving the collaborative efforts between businesses and the research community is another must-have. Local businesses typically have little awareness of the breadth of capabilities that lie within the research community and even fewer have structures in place to take advantage of them. Adding to the difficulty are overly complicated intellectual property arrangements, priority misalignment (publications and grants of research vs. commercial outcomes of industry), and a lack of quality translators who can understand both business needs and scientific solutions.

While industry and government bodies provide some level of public information, it is typically at a very high level and scattered across the many organizations at each level of industry and government. Further, many businesses are unaware of the support that exists, possibly again due to the complex network of supporting organizations and initiatives.

One of the more successful models for collaboration between government, private-sector companies, universities, and research facilities has been in Australia, where the strategic advisory arm of Australia's national science agency CSIRO Futures has laid out a roadmap for addressing food security and nurturing the development of Australia's agriculture sector¹³. With a small domestic market and industry consisting of relatively small businesses, collaboration is essential for achieving scale, efficiency, and agility across changing value chains and markets.

Several steps can be taken to improve collaboration efforts:

- Leverage government networks and innovation support schemes
- Identify potential collaborations with international partners (not only with private sector but also with other international agencies and governments); put key players to work together towards the goal
- Develop business consortium and boost companies to become global champions and establish long term arrangements and partnerships
- Provide more holistic R&D solutions
- Simplify intellectual property arrangements
- Establish "end-to-end" pilot programs

Attract talented and skilled collaborators who bring to the table a problem-solving mentality. To achieve the goal a target, governments should look for the best talent to contribute to the program. The best talent will not come easily and competition is strong. Differentiating in your attraction plan is key:

- Provide high quality job opportunities
- Communicate your intentions to show global experts see it is a unique global opportunity that will have a global impact

Governments should invest in the entire food chain, identifying high potential entities that can support the vision of ending hunger and food scarcity. They must make targeted investments that emphasize synergies, collaboration, and communication: developing business consortia, providing holistic R&D solutions, simplifying intellectual property arrangements, and establishing "end-to-end" pilot programs. Other investments should focus on education and raising people's skills level. This means increased spending on data science; hire business development staff and mobilize researchers into industry. Finally, governments should launch educational programs around the urgency of food crisis, educating people and companies about optimizing food supplies and eliminating waste.

13. CSIRO Futures: Food and Agribusiness: A Roadmap for unlocking value-adding growth opportunities for Australia (July 2017)

Depending on the stage of technology and maturity of the players, governments will have to play different roles. In the case of mature companies, this will involve support through longer-term partnerships and access to markets, incentives via direct investment or tax breaks, and regulatory flexibility. For startups and emerging players, governments can assist by easing administrative work, leveraging their connections, providing seed capital, land, and infrastructure.

- Allocate investments to the food program
- Identify potential deals to invest in across the entire value chain and with different short- and long-term perspectives
- Focus on both establish and emerging players with innovative and like-minded mentality
- Investigate early-stage research startup, not just commercially oriented companies
- Explore cross-industry opportunities to invest in and create new solutions by merging them with agricultural activity (similar to 3D printing entering the food industry)

- Establish clear investment criteria, balancing both impact investments towards addressing the goal of identifying potential synergies, and financial investments to maintain returns and future investments flows

Create educational programs and awareness initiatives:

- Launch educational programs around the urgency to address this global issue and educate people and companies around optimizing food supplies and food-waste solutions
- Plan a strong communication campaign
- Cover every relevant entity and event, including Schools, universities, private companies and local and international events
- Establish incentives and/or an award system to ensure good behavior and consciousness around the issue

APPENDIX A.

AEROFARMS INTERVIEW WITH DAVID ROSENBERG, CEO, AEROFARMS

1. WHAT ARE THE REASONS YOUR COMPANY INVESTED IN FOOD TECH?

Since 2004, AeroFarms has been working to solve the global food crisis by building, owning, and operating indoor vertical farms that grow safe, nutritious, delicious food all over the world, setting a standard for controlled agriculture and transforming our food system in an environmentally sustainable and socially responsible way.

2. WHY SHOULD A CITY OR A GOVERNMENT INVEST IN FOOD TECH?

A local food tech industry generates many benefits for municipal governments including food security and resiliency. New facilities/companies can lead to job growth and spur additional economic development. Locally grown produce can improve nutrition for urban populations, reducing the strain on healthcare systems in the future.

3. WHAT IS YOUR COMPETITIVE ADVANTAGE COMPARED TO TRADITIONAL AGRICULTURE AND OTHER FOOD TECHNOLOGY?

AeroFarms' approach to indoor vertical farming reduces agricultural inputs while also boosting productivity. We use 95 percent less water, substantially less fertilizer and nutritional supplements, and no pesticides. We grow produce year-round, allowing us to reach potential productivity yields greater annually compared to a traditional field farm of the same square footage. Our production is independent of severe weather events or seasonal change. Further, because our product is locally grown and not imported from abroad, our produce stays fresher for longer on supermarket shelves and in home refrigerators.

4. WHAT ARE YOUR MOST RECOGNIZED ACHIEVEMENTS/PRODUCTS?

Recognized by Inc.com magazine as one of the Top 25 Disruptors changing business around the world, AeroFarms has successfully grown more than 300 different types of leafy greens and herbs and has started to explore other potential applications of its technology. We lead the world in high-tech, data-driven, commercial-scale vertical farming.

5. HOW BIG IS THE BUSINESS OPPORTUNITY IN FOOD TECH FOR A COUNTRY AND SPECIFICALLY FOR THE MIDDLE EAST?

A large portion of the Middle East's fruits and vegetables are imported. In 2016 alone, the UAE imported 4.2 million tons of fruits and vegetables according to the UN Comtrade database. Building a cost-effective commercial-scale business that provides fresh produce to local populations should be invaluable.

6. HOW CAN FOOD TECH HELP THE LOCAL ECONOMY?

Going forward, UAE advanced manufacturing jobs will represent an increasing portion of the domestic economy. Creating a local ecosystem of innovation will encourage UAE residents to stay and work locally; the food-tech space could function as a vital employment sector for engineers, scientists, and entrepreneurs.

7. HOW CAN A GOVERNMENT SUPPORT YOUR COMPANY IN IMPLEMENTING AND IN EXPANDING LOCAL FOOD TECH SOLUTION IN ITS COUNTRY?

Indoor vertical farming relies on affordable electricity rates to be cost effective. Governments could further support the development of these farms by offering power cost subsidies or other development tax incentives. They can support the distribution of fresh local produce in impoverished areas and educate their citizens on the benefits of healthy eating.

8. HOW DO YOU SEE FOOD TECH IN 15 YEARS? HOW IS IT GOING TO EVOLVE?

We envision a world where fruits and vegetables are grown not only to maximize pest resistance and minimize spoilage but also for taste preferences of local populations. A world where food supply chains and ingredient lists are streamlined to remove preservatives and other artificial flavors. A world where global rates of malnutrition are on the decline, not the rise.

9. WHICH COUNTRIES WILL TAKE LEADERSHIP IN THIS NEW INDUSTRY?

Countries with a highly educated population, low energy costs, and a government willing to engage in public-private partnerships will ultimately become the world leaders in this space.

10. WHAT ARE THE BIGGEST CHALLENGES FOR THIS TECHNOLOGY OR YOUR COMPANY?

One of our biggest challenges is identifying the right countries and local partners to develop our platform. The complexity in building out large, commercial farms and food safety are often underappreciated by newcomers to the industry.

APPENDIX B.

OLIO INTERVIEW WITH TESSA COOK, CO- FOUNDER, OLIO

1. HOW DOES OLIO WORK?

OLIO is a free app tackling the problem of food waste by connecting neighbours with each other and with local shops and cafes so that surplus food can be shared, not thrown away. Users simply snap a picture of their items and add them to OLIO. Neighbours then receive customized alerts and can request anything that takes their fancy. Pickup takes place – often the same day – at the home or another agreed location. Items typically found on the app include food nearing its use-by date from shops, cafes, and markets; spare vegetables from the allotment; cakes from an amateur baker; or groceries from household fridges when people go away, move home, or start a diet. All the food on OLIO is either available for free or for a “pay as you feel” donation to charity, and 40 percent of food listings are requested within one hour of being added to the app!

OLIO also has a Food Waste Heroes programme whereby we recruit volunteers via the app who provide a service to our retailer partners whereby they collect unsold food at the end of the day, take it home, add it to the app, and redistribute it to the local community. Our partners include leading UK supermarkets and food-on-the-go chains such as Pret a Manger, Tesco, Sainsbury's, and Morrisons.

With approximately 350,000 users, OLIO is the world's only neighbour-to-neighbour food sharing app. However, we wouldn't be where we are today were it not for our 15,000 and counting Ambassadors (volunteers) who spread the word about OLIO in their local community.

2. HOW DOES IT HELP ADDRESS THE FOOD SCARCITY ISSUE?

Food waste is one of the largest problems facing humanity today. Globally, over a third of all the food we produce is thrown away, which is worth over \$1 trillion, meanwhile 800 million people go to bed hungry each night. Food waste is also devastating for the environment: A land mass larger than China is used to grow food each year that is never eaten. If food

waste were to be a country it would be the third largest emitter of greenhouse gases, after China and the US!. What a lot of people don't realize however is that in the “developed” world, approximately half of all food waste occurs in the home. And so in the UK, households bin over £13 billion of edible food per year, at a cost of £700 to the average family! And at the same time we have 8 million people living in food insecurity, half of whom are living in severe food insecurity. Through ensuring that surplus food in the home and local community is eaten, not thrown away, OLIO is not only unlocking the economic value of that food, but is also unlocking the nutritional, environmental, social, and moral value of that food. The result is good for individuals, good for communities, and good for the planet. So far, OLIO has facilitated the sharing of almost half a million portions of food, which is the environmental equivalent of taking over 1 million car miles off the road!

3. WHAT CAN A GOVERNMENT DO TO IMPROVE THE SOLUTION?

Governments have access to capital and routes to market, which are two things that are very hard for a startup to unlock. We have already spoken to a handful of international city governments who are interested in how OLIO can be implemented in their cities; and we currently work with several UK local governments as well. With approximately one-third of all municipal waste being food waste – which is extremely costly to collect and dispose – and record levels of hungry citizens, local governments are recognizing that the time has come for innovative digital solutions such as OLIO.

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