

Sustainable and Resilient Foods for Future Generation

Authors

Matthieu De Clercq
Anshu Vats
Alvaro Biel
Etienne Raynaud

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Introduction

The food crisis of 2007–2008 shook both developed and developing countries to the core. Between 2006 and 2008, the average world price for oil rose by 110 percent¹, rice by 217 percent, wheat by 136 percent, maize by 125 percent, and soybeans by 107 percent². Even cities said to be relatively food secure like Singapore were taken by surprise, with food-import prices increasing by 12 percent³. What happened next? Between 2010 and 2012, food prices reached new heights. In 2011, Robert Zoellick, former World Bank president, warned that the world was “one shock away from a full-blown crisis”. What has changed since then? Have governments taken the necessary steps to make their countries and cities more food secure? Or are we one step away from the next global food crisis?

This paper does not offer a prediction as to if or when the next food crisis will occur. However, it defines what challenges lie ahead, and offers countries and cities a framework to assess how food secure they are and the necessary tools to do something about it.

For the world to be food secure, countries and cities need to ensure that all aspects of their food supply chain are in check, from farm to fork, whether imported or locally produced. While several countries have put much emphasis on food production, it is important to remember that one cannot be food secure without processing facilities, necessary infrastructure, and logistics, as well as adequate distribution channels. Food security does not permit weak links.

Our food systems do not operate in isolation. They are part of an environment, and the road ahead is paved with hurdles. Indeed, given the dramatic advance of climate change and increasingly severe weather events, as well as population growth, increased urbanization, aging population, changing dietary patterns, and decreased arable land, our global food system will need to become both more resilient and climate resistant. This paper offers an analysis into each of these challenges to assess how our food systems need to adapt.

If anything is evident, meeting future food demand will require a complete reinvention of our global food system away from the current status quo. This will mean rethinking and restructuring everything from the technologies we use, the scale of investments in the agriculture and food sector, to our welfare programs and diets. We will need to produce more and better. While no country or city start at the same point, all need to adapt. From net exporters to importers and from urbanized Singapore to highly deserts Saudi Arabia, there is no one solution that fits all.

This paper analyzes key levers for each aspect of food security to provide countries and cities with a clear picture of what can be done and a roadmap to enable them to develop long-term food security strategies and in so doing meet their populations’ most basic need. Not only will countries and cities need to produce more, they will need to produce more in the face of increasing disruption. To that end, we will propose insights into the next wave of climate resistant technologies that will push our global food system into the 21st century.

Global challenges will require global cooperation. In facing megatrends such as a population boom in a hyper-urbanized world, countries cannot afford to leave corners of the world with unexploited agricultural potentials. Increased investment and technology transfers are sorely needed. With climate change disrupting entire supply chains and generating waves of climate and food refugees, it is clear no country will be able to claim to be food secure without regional and international cooperation.

1. The impact of oil prices fluctuations on transport and its related sectors,” European Parliament (2009)

2. Food Prices in Agricultural Markets (<https://are.berkeley.edu/~sberto/foodCrisis.pdf>)

3. <https://www.channelnewsasia.com/news/singapore/commentary-can-farming-be-a-success-story-for-singapore-8577514>

1. Understanding the Current Status Quo

The issue of food security affects each country and city in different ways, and their needs in terms of achieving security vary accordingly. Some cities and countries must put their efforts into addressing demand-side initiatives, whereas others should focus on the supply side of the equation.

In assessing the existing conditions of food security, we have taken a number of critical areas into consideration. “Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life”⁴. From this definition, we identify the following five key dimensions of food security: availability, physical access, economic access, utilization, and sustainability.

- **Food availability:** Food availability addresses the “supply side” of food security and is determined primarily by the level of domestic food production as well as reliance and diversification of imports
- **Physical access to food:** Physical access is determined by the access of households to food they require through their own production or more commonly the marketplace
- **Economic access to food:** Economic access is determined by households’ ability to purchase required amount of food. Fluctuation in critical food item prices and purchasing power will be determinants of that access
- **Food utilization:** Utilization is determined by both food safety and nutritional content and is the result of good care and feeding practices, food preparation, diversity of the diet, and intra-household distribution of food
- **Sustainability:** For food security objectives to be realized, the above mentioned four dimensions must be fulfilled simultaneously and over time⁵. Even if a household food intake is adequate today, it may still be considered food insecure if it has inadequate access to food on a periodic basis

The Role of Availability in Food Security

Availability of food is the basic dimension of food security—particularly to the supply-side aspect to the issue. The key considerations for availability are the levels of domestic food production and stock levels, as well as net trade.

One of the core issues of availability is increasing domestic food production through increased farm productivity or surfaces dedicated to production. Food availability is subject to and heavily influenced by agro-climatic conditions and a range of socioeconomic and political factors that determine the ability of farmers to operate. However, no country relies 100 percent on domestic production to meet all its food demand and as a result food imports play an important role in food security. Depending how heavily a city or country rely on imports and how diversified its sources of supply are, will determine how secure it is.

The Role of Physical Access in Food Security

The second key dimension in food security is physical access to food: There must be an adequate amount of food within the physical reach of households, whether via their own production or through the marketplace. Poor access may be the result of inadequate places to shop for food or the result of physical barriers.

Some common threats to achieving physical access to food include poor infrastructure along the food supply chain from production to retail centers. It is estimated that around one-third of all food produced globally is wasted representing a cost of US\$1 trillion annually⁶ driven by the lack of adequate infrastructures.

4. 1996 World Food Summit
5. FAO Food Security Program
6. UNESCO

The Role of Economic Access in Food Security

The third dimension is economic access to food or the ability of the household to purchase the food it requires. The key elements of this dimension are the purchasing power of consumers and the evolution of real incomes and food prices.

This is the dimension most relevant to urban residents who have to purchase almost all of their food. As recent food crises have demonstrated, urban households were among the hardest hit, as they saw their purchasing power decline drastically and they had very limited capacity to produce their own food. Additional factors that will influence economic access include employment and income security, macroeconomic policies, social security programs, and of course, the availability of food through its impact on market supply, and therefore on market price.

The Role of Food Utilization in Food Security

The fourth dimension is food utilization. While households may have the capacity to purchase the food they need, they may not be able to utilize it in a safe or nutritional manner. It is not enough that an individual is getting what appears to be an adequate amount of food if that person is unable to consume it. Food utilization revolves around what is typically thought of as health conditions: the quantity and quality of dietary intake, general child care and feeding practices, food preparation, and food storage, along with health status and its determinants.

Food utilization is dependent on quality as well as quantity. At the moment, the world faces the threat of a triple burden of malnutrition: undernutrition, micronutrient deficiencies, and overweight and obesity. For example, while the consumption of more nutritious foods increased worldwide between 1990 and 2013, the consumption of highly processed foods increased more than the consumption of fresh foods, adding to the problems of undernutrition. According to Rami Zurayk, Member of the steering committee of the High Level Panel of Experts of the world committee on food security, the phenomenon of “stuffed and starved is being experienced by many, in most countries”⁷.

The Role of Sustainability Over Time in Food Security

Sustainability is the ability of a country or city to maintain and possibly improve the four factors that drive food security over time. This dimension is driven by a country or city’s ability both in terms of its institutions and policies to ensure its population has access to the amount of food they require as well as its safety. Country or city must not only have the capabilities to monitor, assess and enforce its standards but also have the ability to improve its food system.

Conclusion: Food security is about more than just producing the required amount of food. In order to be food secure, countries or cities cannot afford to have a weak link that could potentially compromise their food system as a whole. The next section considers the stress on the food supply chain that will need to be integrated in any strategy aimed at improving the five components that make up food security.

7. Full interview available in the Appendix A

2. Impact of Increased Stress on Global Food Systems

Although the rate of world population growth has slowed to an extent in certain parts of the globe, some regions will continue to expand beyond 2050 and into the next century. Moreover, population has shifted across the globe, with more people now living in cities than in rural areas, a discrepancy projected to increase as population grows⁸. This urbanization has been accompanied by a transition in dietary patterns and an aging rural population left to care for food production. Finally, the effects of climate change on all aspects of our global food system are already being witnessed and it is expected that this will only increase in the decades to come with all food security dimensions impacted in the most profound ways. In this section, we examine these six key pressure points and their impact on global food systems.

Increased Population

Though population growth rates for the world as a whole have been declining for the past 50 years (due in part to birth control and higher education levels), the world's population has continued to rise in absolute terms. According to the United Nations' projections, it will reach almost 10 billion in 2050. The impact on global food systems will be substantial: Demand for food is expected to grow 70 percent by 2050 (compared to 2005/2007 levels)⁹. To meet this new demand, agriculture producers will need to grow almost 50 percent more food, feed, and biofuel than they did in 2012. This means that agricultural output in sub-Saharan Africa and South Asia will need to more than double by 2050 to meet increased demand, while in the rest of the world the projected increase would be about one-third above current levels.

Increased Urbanization

Thirty-five years ago, more than 60 percent of all people lived in rural areas. Today, however, more than half of the global population (54 percent) is urban, and the percentage is rising: In 2050, more than two-thirds of all people will be living in cities, resulting in a net addition of 2.4 billion people to towns and cities¹⁰. Urbanization impacts food consumption patterns. Higher urban income levels increase consumer demand for processed foods, as well as meat, fish, fruits, and vegetables. Higher urban wages also increase the opportunity costs of preparing food, favoring products that have a large amount of labor embedded in them, such as fast food, convenience foods, and foods prepared and marketed by street vendors. With these changes, the nutrient content of diets is changing. Typically, diets are becoming higher in salt, fat, and sugar.

An Aging Population

The world population is growing older in both high-income and low-income nations, thanks to improved healthcare and medicine. Adding to the strain on food systems is the trend towards an aging rural population: From sub-Saharan Africa and Asia to Latin America and the Caribbean, there is an increase in the proportion of older people living in rural areas and a decline in the proportion of younger people, with 27.5 percent of agricultural holders aged over 55. The rapidly aging rural agricultural workforce has major implications for the composition of the rural labor force, patterns of agricultural production, land tenure, social organization within rural communities, and socioeconomic development in general.

8. United Nations

9. Ibid

10. Ibid

Changing Dietary Patterns

With incomes rising in developing countries, demand for food is increasing as well, leading to changes in diet, such as eating more protein and meat. Food demand is projected to increase anywhere from 59 percent to 98 percent by 2050, according to certain models (which are somewhat higher than the FAO's projection of a 54 percent increase in demand)¹¹. With a rise in income, which typically accompanies urbanization, high-income consumers will determine the food grown by producers and how that food is traded, processed, distributed, and marketed. High-income consumers will demand access to a greater diversity of foods including meat, dairy products, and convenient processed foods. This will in turn have an impact on advanced logistics, transportation, storage, and processing.

Saturation and Pollution of Arable Land

Land is a finite resource and the world is rapidly outstripping its ability to replace soil that has become diminished and unproductive. Nearly one-third of the world's adequate or high-quality food-producing land has been lost at a rate that far outstrips the pace of natural processes to replace diminished soil, according to research¹². The availability of arable land is shrinking, due to overuse and pollution: 1.4 billion people live in areas with degraded and inadequate groundwater¹³.

Climate Change: The Great Disruptor

Climate change is no longer a matter of conjecture or debate. It is a fact: Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, and global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate, according to the Intergovernmental Panel on Climate Change (IPCC)¹⁴. Levels of greenhouse gas (GHG) emissions are the highest in history¹⁵, and agricultural production and land use are major sources of these emissions. Climate change will affect every aspect of food production. And while higher temperatures can improve crop growth, yields decline significantly when daytime temperatures exceed a certain crop-specific level¹⁶. Additionally, variability in precipitation and increases in droughts and floods are likely to reduce yields, as soil quality, water-table depth, fertility, slope, and pH all have an impact on agricultural production.

The impact of climate change goes beyond the issue of supply and into nutritional quality, access, and the stability of food security over time. Research has found that under conditions of elevated levels of carbon dioxide, the concentrations of minerals in wheat, rice, and soybeans can be up to eight percent lower than normal. Moreover, protein concentrations may also be lower, while carbohydrates are higher¹⁷. Climate change is also likely to lead to an increase in the incidence of diseases, as infectious disease transmission patterns become disrupted. The effects of these disruptions include increased respiratory and cardiovascular disease, injuries and premature deaths related to extreme weather events, changes in the prevalence and geographical distribution of food- and water-borne illnesses and other infectious diseases, and threats to mental health.

Conclusion: The global food system is already showing its limits in dealing with current demand. In the future, it will have to deal with megatrends such as population growth and increased urbanization that on their own make the current status quo unsustainable. Climate change is set to be a major disruptor in our efforts to deal with one of the greatest challenge faced my humankind. As such, meeting future food demand will require far-reaching reforms at every stage of the food supply chain.

11. "The future of food demand: understanding differences in global economic models," by Hugo Valin, Ronald D. Sands, Dominique van der Mensbrugghe, et al. *Agricultural Economics*, 2013.

12. "Earth has lost a third of arable land in past 40 years, scientists say," *The Guardian* (Dec. 2, 2015).

13. UNESCO

14. Special Report on Global Warming of 1.5 °C (http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf)

15. Intergovernmental Panel on Climate Change (IPCC), (Porter et al., 2014).

16. The State of Food and Agriculture (FAO, 2016e). <http://www.fao.org/publications/sofa/2016/en/>

17. The State of Food Insecurity in the World (FAO, 2015)

PRIMARY CAUSES OF DEGRADED FARMLAND

Degradation of farmland has many different causes, some of which lead directly to ruined farmland, 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 and a cause of other kinds of despoliation, principally water erosion
- **Overcutting vegetation:** Overcutting has led to water erosion and wind erosion, resulting in land less suitable for food crops
- **Inadequate fallow periods:** Allowing land to go fallow was once a tried and true method of restoring soil nutrients. But in the face of growing economic pressures, shortened fallow periods are helping to compound soil erosion
- **Overgrazing:** Livestock overgrazing decreases vegetation cover, which in turn leads to a decline in the soil's resistance to erosion
- **Improper crop rotation:** Farmers have adopted intensive, cereal-based crop rotations, in place of more balanced rotations
- **Unbalanced fertilizer use:** The effort to maintain crop yields via indiscriminate use of fertilizer has led to soil-nutrient imbalance

3. Metropolitan Areas Cannot Rely on One-Size-Fits-All Solutions

The five dimensions of food security differ significantly in importance between urban and rural environments. In cities, food availability and distribution are vital to ensuring food security. However, no two cities are the same: Each one faces its own challenges. We examined five cities: New York, Singapore, Riyadh, Dubai and Havana to assess how secure they are along the five dimensions.

DID YOU KNOW?

No city on this planet can claim to be completely food secure.

NEW YORK CITY

- Population: 8,622,698¹⁸
- Population under 18 years, percent: 21.2 percent
- Population 65 years and over, percent: 13 percent
- Median per capita income: \$64,894¹⁹
- Temperature range: high 88°F; low 26°F
- Rainfall range: 4-inch per month
- Food security ranking: 3

Strengths

Food availability: The role of the US as a major food producer significantly strengthen New York in terms of food supply.

Weaknesses

Physical access: Food deserts are dotted throughout the city, mostly in poor neighbourhoods where there are no supermarkets to serve the local community. In these areas, unbalanced diets are common, leading to negative consequences such as cognitive impairment, low resistance to disease, and increased risks during childbirth.

Economic access: An estimated 1.4 million New York City residents rely on emergency food programs, including soup kitchens and food pantries, each year²⁰. **Utilization:** Residents of poor and underprivileged neighbourhoods are more likely to consume sugary drinks and less likely to eat fruits and vegetables when compared with residents of NYC overall.

18. 2017 US Census Bureau

19. US Census Bureau <https://www.census.gov/programs-surveys/acs/>

20. Food Bank for New York City

DID YOU KNOW?

There were 1.25 million food-insecure New Yorkers at least some time during 2015.

Food Bank For New York City's food distribution program provides approximately 62.5 million free meals per year for New Yorkers in need. Since 1983, Food Bank For New York City has provided more than one billion meals to New Yorkers.

SINGAPORE

- Population: 5,638,700
- Population under 18: 14.5 percent
- Population over 65: 9.7 percent
- Median per capita income: \$52,867²¹ in 2017
- Temperature range: high 90°F; low 76°F
- Rainfall: range: high 12.5 inches; low 4.4 inches
- Food security ranking: 1

Strengths

Physical access: trans-shipment hub in Asia with significant transport and logistical infrastructures.

Economic access: High income per capita, low tariffs and barriers to trade, stable currency, and economic stability. **Utilization:** stringent food safety standards.

Weaknesses

Availability: There is very little local production in Singapore and the country is heavily reliant on imports. Although the city has engaged significant reforms since the 2007-08 food crisis, its import diversification and local stock development strategy needs to go further to offset its import reliance.

DID YOU KNOW?

Singapore imports more than 90 percent of the food requirements for its 5,638,700 inhabitants.

21. <https://www.singstat.gov.sg/-/media/files/publications/reference/sif2018.pdf>

RIYADH

- Population: 6,937,399
- Population, 65+: 3.163 percent
- Population, 15 and under: 24.8 percent
- Median per capita income: \$20,761²²
- Temperature range: high 110°F; low 49°F
- Rainfall range: high 0.646 inches; low: 0.044 inches
- Food security ranking: 3

Strengths

Economic access: Oil revenue and subsidy programs enable the country to meet all its food requirements.

Weaknesses

Availability: Heavy import reliance, limited local production and increasing consumption pose a significant risk to city's food security, particularly in time of low oil prices. **Physical access:** The country as a whole and Riyadh have the highest rate of food waste globally. **Utilization:** Changes in lifestyle and Western-style diets are causing growing obesity issues, with 34 percent of the adult population considered obese in 2014.

DID YOU KNOW?

Urbanization rate in KSA has been growing over last 25 years to reach 83 percent in 2015.

DUBAI

- Population: 2,785,376
- Population, 65+: 31,900
- Population, 15 and under: 414,510
- Median per capita income: \$41,197²³
- Temperature range: high 57°F; low 106°F
- Rainfall range: high 1.57 inches; low: 0.39 inches
- Food security ranking: 31

Strengths

Physical access: Significant transport and logistical infrastructures. **Economic access:** High income per capita, low tariffs and barriers to trade, stable currency, economic stability, An abundant and inexpensive energy supply. **Food utilization:** Strong regulatory frameworks.

Weaknesses

Availability: Although Dubai has diversified its import partners over the past years, it will have to go further to offset its lack of significant domestic production. **Physical access:** The country as a whole and Dubai have one of the highest rates of food waste globally. **Utilization:** Changes in lifestyle and Western-style diets are causing growing obesity issues, with 37 percent of the adult population considered obese in 2014.

22. The World Bank <https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=SA>

23. <https://tradingeconomics.com/united-arab-emirates/gdp-per-capita>

DID YOU KNOW?

Despite importing between 80 percent to 90 percent of its food supplies, the UAE is considered food secure due to its capacity to purchase food on the international market even if at higher costs.

Food consumption in the UAE is growing due to the influx of tourists, and to overall population growth.

HAVANA

- Population: 2,129,553
- Population, 65+: 335,789
- Population, 15 and under: 306,892
- Median per capita income: \$384
- Temperature range: high 90°F; low 79°F
- Rainfall range: high 3.149 inches; low 0.39 inches
- Food security ranking: 113+

Strengths

Economic access: Broad social protection initiatives have eradicated poverty and hunger. For example, as part of the social safety net, families receive a monthly food basket, school feeding programs, and mother-and-child health care programs.

Weaknesses

Availability: The city is highly reliant on imports and its local production has a low level of productivity. In addition, there is a high prevalence of tropical storms, hurricanes, heavy rainfalls, and drought that contribute to its production issue. **Utilization:** Low food availability impact the ability of the population to access a diverse diet.

DID YOU KNOW?

Cuba relies on imports for 70 percent to 80 percent of its domestic food requirements.

The diet of the average Cuban family is poor in micronutrients with few vegetables consumed and low food diversity.

When examining these core components, countries or cities around the globe have different strengths and weaknesses. As a result, no single size solution fits all of them. While it is clear that some places are better off than others, no city or country can pride itself on being completely food secure. Considering current vulnerabilities and challenges ahead, it is now more important than ever for governments around the world to develop the appropriate framework to establish a system diagnostic and launch strong and ambitious initiatives to strengthen their food security.

4. Governments can Leverage a Series of Key Food Security Enablers

4.1 Food Security Dimensions Enablers

To make progress in the five dimensions of food security—availability, physical access, economic access, utilization, and their stability over time—it is critical to leverage the key enablers examined below:

EXHIBIT 1: FOOD SECURITY ANALYTICAL FRAMEWORK

1 Food security components	Availability	Physical Access	Economical access	Utilization	Sustainability
	Population growth	Increased urbanization	Aging population	Changing dietary patterns	Saturation and pollution of arable land
2 Food security challenges	Climate change				
	Availability	Physical Access	Economical access	Utilization	Sustainability
3 Food security enablers	<ul style="list-style-type: none"> Local production Local stocks Production inter. Import diversify 	<ul style="list-style-type: none"> Infrastructure and cold chain Retail sector regulation 	<ul style="list-style-type: none"> Price increase mitigation mechanisms 	<ul style="list-style-type: none"> Food safety and nutrition regulation High-nutrition product demand 	<ul style="list-style-type: none"> Strong regulatory and institutional framework
	Climate resilient technologies				
	Investment				

Source: Olivey Wyman analysis

Availability Enablers

Local production: Beyond new climate resistant production technologies that will be reviewed below, countries or cities have several tools at their disposal to develop local production. For example, they can improve farm management practices or invest in technologies that will increase crop productivity. Singapore has invested heavily in this strategy: each farm has a dedicated Agri-Food and Veterinary Authority expert advising on how to best leverage new technologies, increase commercial potential and obtain the necessary government approvals. In addition, when land is tendered for farming, it is at fixed price, and tenders are assessed on how innovative they are.

Production internationalization: Countries around the world with limited or saturated arable land have developed programs to buy land overseas, develop their agricultural potential and export the farms' output back to them. According to Yousrey El Sharkawi, former Food Security Consultant at UAE Ministry Of Environment & Water, 10 years ago Gulf countries decided to step up their food security and their "first action was to make contracts to outsource the production in places like Sudan or Pakistan, for example, and then in South and Central America, and Azerbaijan, as well as Brazil"²⁴. For example, in 2016, Saudi Arabia bought 14,000 acres of US farmland in California and Arizona to grow alfalfa to feed its livestock²⁵. In Sudan alone, South Korea has signed deals for 690,000 hectares,

24. Full Interview available in Appendix B

25. CNBC [<https://www.cnbc.com/2016/01/15/saudi-arabia-buying-up-farmland-in-us-southwest.html>]

the United Arab Emirates (UAE) for 400,000 hectares and Egypt has secured a similar deal to grow wheat²⁶.

Import diversification: To sustain disruption in supplying countries, food import reliant countries can diversify sources through the establishment of quota per supplying country or the development of government capabilities to support the private sector in identifying new opportunities abroad. For example, leveraging this strategy Singapore started importing live pigs from Malaysia to reduce its vulnerability to potential disruptions in Indonesia, which use to be its exclusive supplier.

Food stocks: Another strategy to mitigate the impact of disruptions, involves the development of strategic food stocks. Country or cities will typically mandate large importers to build up a minimum amount of stocks to be able to meet demand for a few months. However, this will require the development of the appropriate infrastructures to implement such policy sustain short to medium term disruptions.

Physical Access Enablers

Supply chain infrastructure: Globally less than 10 percent of the perishable foodstuffs are currently being refrigerated. It is estimated that “improving access to refrigeration in developing countries could prevent the spoilage of up to 23 percent of perishable foods currently produced in these countries”²⁷. Most developing and emerging countries currently lack the basic infrastructure and management skills needed to support the development of integrated cold chains for distribution of perishable foods. One response have been for countries or cities can set up specialized funds to provide preferential loans to public and private stakeholders seeking to develop these infrastructures.

Retail sector regulation: Cities and countries around the world have sought to address food desert and waste at retail level through increased sector regulation. For example, a study showed that, opening a supermarket in a food desert neighborhood decreases people’s daily caloric intake by 222 calories and their consumption of added sugar²⁸. Several countries now regulate the amount of food that can be wasted by retailers. For example, in 2016 France became the first country to ban supermarkets from throwing away unsold food.

Supermarkets are no longer allowed to throw away good quality food approaching its “best-before” date; instead, they are required to donate surplus food to charities and food banks. In Denmark, it is legal to sell date-expired food so long as it is clearly labeled and shows no sign of health risk.

Economic Access Enablers

Price increase mitigation mechanisms: Policies to mitigate significant food prices for critical food items can typically be defined into three categories: trade oriented, consumer oriented, and producer oriented. First, trade-oriented initiatives typically use tariff reduction and export restriction in case of significant upward price fluctuation. For example, when Russia announced in 2010 the suspension of its wheat exports in the wake of its drought and wildfires, wheat price spike by more than half. In response, Ukraine, Belarus, Uzbekistan, and Kazakhstan also restricted or banned wheat exports. Second, consumer-oriented initiatives directly support households with subsidies, price controls, or emergency food programs. For example, as mentioned above cities such as New York have developed emergency and distribution food programs providing millions of free meals to low-income groups. Finally, producer-oriented initiatives support farmers with subsidies or output price control.

Food Utilization Enablers

Food safety regulation: Strict food safety standard is paramount to ensuring proper food utilization and maintaining consumer confidence in the food system. It has been estimated that globally foodborne diseases were responsible for 33 million deaths annually²⁹. In the US, it is estimated that the total economic impact of foodborne illness is around \$152 billion annually. As a result, many countries have started shifting the focus of food safety from reaction to prevention. For example, the Obama administration modernized the FDA to achieve higher rates of compliance with food standards through increased prevention efforts. New powers included, among others, mandatory preventive controls for food facilities, mandated inspection frequency.

26. The Economist [<https://www.economist.com/international/2009/05/21/outsourcings-third-wave>]

27. The International Institute of Refrigeration (IIR, 2009)

28. NIH [<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4457716/>]

29. WHO

Nutrition regulation & demand: Governments around the world are coming under increased pressure to regulate salt, sugar, and fat in processed food in terms of either content or through increased labeling standards. For example, the maximum content of sodium in selected processed foods in Argentina was limited by a law enacted in 2013. In 2016, the United Kingdom government mandated sugar level reduction in products which contribute most to the sugar intake of children.

4.2 Cross Dimension Enablers

Climate Resilient Production Technologies

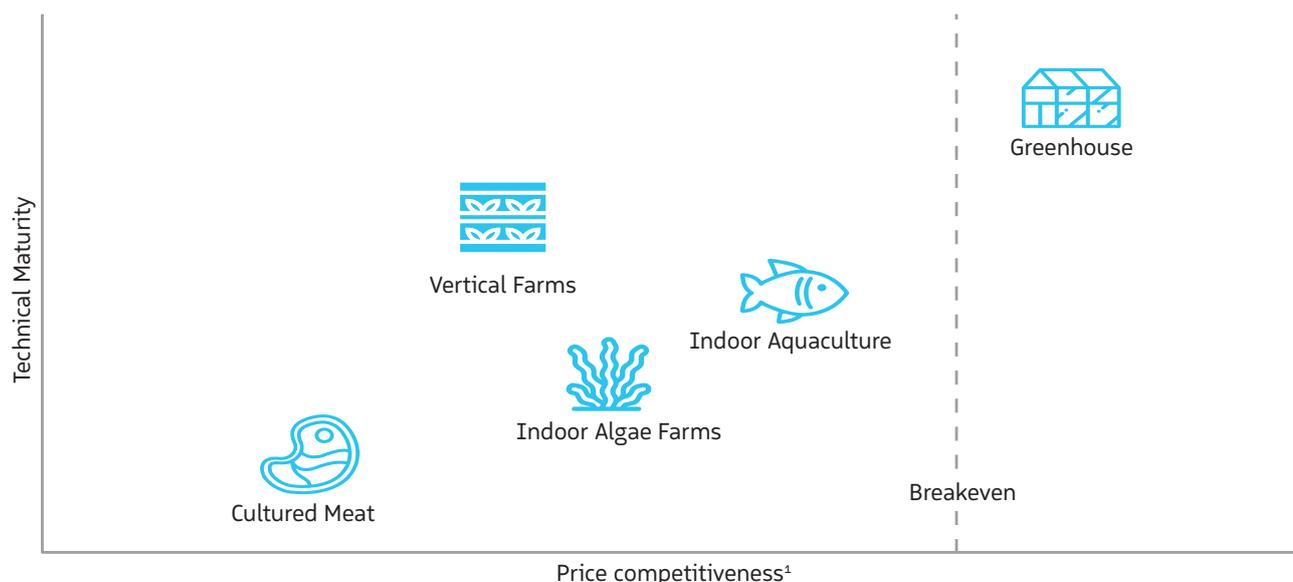
Technologies to produce food more effectively, which also can increase resilience to climate change, already exist, albeit with different levels of maturity, investment requirements, and technological complexities. We examined five indoor – climate resistant – farming technologies that have been developed in the past few years and that all have a high disruption potential with marked improvements from their conventional counterparts.

Greenhouses: High tech greenhouses with semi or fully closed environment produce food year-round. Greenhouse is mature technology with a proven

track record in countries such as the Netherlands or China. The market is currently estimated at US\$ 20 billion and expected to grow by seven percent annually³⁰. In the past few years, more and more companies have developed technologies to enable production in a variety of harsh environments, from dry desert conditions to cold climates. For example, new cooling technologies using seawater and soil-less plant growth systems such as hydroponics or aeroponics could allow countries such as the United Arab Emirates or Saudi Arabia to produce to produce fruits and vegetables competitively despite the lack of arable land and fresh water scarcity.

Vertical farming: Vertical farming is by far the most disrupting technologies in urban farming. Indeed, vertical farms using hydroponics or aeroponics have outperformed both conventional farming and greenhouses in terms of productivity; with the help of urban farming, one can produce even so much as 100 times more food than with conventional farming (per square foot). Additional benefits include low water usage with 95 percent decrease compared to conventional farming, pesticide free produce. Vertical farms' location in urban areas also considerably lower transportation costs as well as carbon dioxide emissions. However, vertical farms are not yet fully competitive due to significant energy costs due to the use of artificial lights and energy intensive temperature and humidity control systems.

EXHIBIT 2: CLIMATE-SMART VERSUS CONVENTIONAL FARMING



1. Price competitiveness compared to conventional counterpart

Source: Oliver Wyman analysis

30. Technavio report, "Global greenhouse horticulture Market 2015-2019"

Indoor aquaculture: Today aquaculture meets more than half of the world’s fish demand which is projected to rise by more than 20 percent to 27 million tons by 2030³¹. While traditionally most aquaculture has taken place out in the sea, issues of disease outbreaks, pollution as well as nuisance to the neighboring population have made such facilities less and less popular. More and more companies are now testing and developing indoor facilities using tanks to grow fish. Indeed, new advancements in water filtration and circulation make it possible for indoor fish farms to dramatically increase scale with low water usage and environmental impact. Recently, a Norwegian firm announced plans to build a \$500 million salmon farm in the US, complete with what it claims is one of the biggest aquaculture tanks in the world.

Cultured meat: This innovative meat is grown by in vitro cultivation of animal cells, using tissue-engineering techniques. Given its lower environmental footprint as compared to traditional livestock raising techniques, cultured meat has the potential to revolutionize the food industry. The process requires less land (anywhere from 90 percent to 95 percent less), emits 96 percent fewer greenhouse gases, and uses up to 96 percent less water. Currently, a number of companies are working on cultured beef, chicken, and duck meats and expect to become commercially viable over the next few years. However, lab grown meat is priced today at \$80 per kilogram, almost ten times more expensive than traditional beef.

Indoor algae production: The interest in micro-algae for human and animal nutrition has increased significantly. With meat consumption rising—and along with it roughly 80 percent of harvested soy and other feedstock going towards feeding livestock—one solution is to use algae as protein sources to feed livestock. Algae contains up to 70 percent protein by dry mass, essential amino acids, and high amounts of micronutrients such as iron. The algae market is currently estimated at US\$ four billion and is expected to grow annually by five percent³². Currently, most companies in the algae industries are focusing on high value products and developing their technologies to bring down cost and expand in the animal and fish feed market further.

Climate-smart technologies can help address the challenge of how to transition to a climate-resistant agriculture. Although they have the potential to disrupt our entire global food systems, investment requirements make their likely impact more moderate.

EXHIBIT 3: CULTURED MEAT PRICE COMPETITIVENESS



Source: Companies’ websites, media scan, Oliver Wyman analysis

31. FAO

32. Fish 2.0 report

Investments

Increased investment in food production, downstream services and R&D is paramount in creating an optimal environment to strengthen food security. A FAO report estimated the global investment gap in agriculture at US\$209 billion annually with a required increase of around 50 percent for developing countries where annual investments stand at US\$142 billion. According to Tony Portman, former Head of Department of Agriculture and Food for FAO in Western Australia “there are a lot of areas in the world that are very fertile where they don’t have technology input”³³.

The R&D investment picture is mixed with the private sector increasingly taking over. Between 2009 and 2013, following the financial crisis, public R&D spending in developed countries decreased by 1.5 percent annually, to reach US\$17 billion in 2013³⁴. However, during that same period, private sector R&D spending in agriculture increase by six percent annually to reach US\$32 billion³⁵.

Nevertheless, there are some encouraging signs. Investment in agriculture and food tech space shot up more than 27 percent annually between 2014 and 2017 from US\$3 to more than 10 US\$ billion with downstream investment representing around 60 percent of total investments. The growth in the number of investors in this sector is also promising with a 77 percent annual increase from 2014 to 2017, to reach 1487 unique investors. Over the 2005-2017 period, the number of investment funds dedicated in food and agriculture increased from 38 to 446 with over US\$ 73 billion under management³⁶.

33. Full Interview available in Appendix C

34. UNESCO

35. Ibid

36. World Investment Report 2017, United Nations Conference on Trade and Development

EXHIBIT 4: INITIATIVES TO STRENGTHEN FOOD SECURITY IN CITIES AROUND THE WORLD

NEW YORK		
FOOD SECURITY COMPONENTS	SCORE	PROPOSED ENABLERS
Food availability		<ul style="list-style-type: none"> Increase local production through urban farming
Physical access to food		<ul style="list-style-type: none"> Increase retail sector coverage in low income neighborhood Regulate retail sector to reduce food loss
Economic access to food		<ul style="list-style-type: none"> Increase stabilization mechanisms to mitigate price hike
Food utilization		<ul style="list-style-type: none"> Increased nutritional content regulation for processed items Develop demand for high-nutrition products
SINGAPORE		
Food availability		<ul style="list-style-type: none"> Increase local production through urban farming Increase import diversification to mitigate disruptions Expand public stocks for additional critical food items
Physical access to food		<ul style="list-style-type: none"> Regulate retail sector to reduce food loss
Economic access to food		<ul style="list-style-type: none"> Increase stabilization mechanisms to mitigate price hike
Food utilization		<ul style="list-style-type: none"> N/A
RIYADH		
Food availability		<ul style="list-style-type: none"> Develop local production through indoor farming Increase import diversification to mitigate disruptions Expand public stocks for critical food items
Physical access to food		<ul style="list-style-type: none"> Strengthen infrastructures and cold supply chain Increase retail sector coverage Regulate retail sector to reduce food loss
Economic access to food		<ul style="list-style-type: none"> Increase stabilization mechanisms to mitigate price hike
Food utilization		<ul style="list-style-type: none"> Increased regulation on processed food nutritional content Develop demand for high-nutrition products
DUBAI		
Food availability		<ul style="list-style-type: none"> Develop local production through indoor farming Increase import diversification to mitigate disruptions
Physical access to food		<ul style="list-style-type: none"> Regulate retail sector to reduce food loss
Economic access to food		<ul style="list-style-type: none"> Increase stabilization mechanisms to mitigate price hike
Food utilization		<ul style="list-style-type: none"> Increased regulation on processed food nutritional content Develop demand for high-nutrition products
HAVANA		
Food availability		<ul style="list-style-type: none"> Develop local production through indoor farming Expand stocks for critical food items
Physical access to food		<ul style="list-style-type: none"> Strengthen infrastructures and cold supply chain Increase retail sector coverage Regulate retail sector to reduce food loss
Economic access to food		<ul style="list-style-type: none"> Develop subsidy mechanisms to diversify diet
Food utilization		<ul style="list-style-type: none"> Increased regulation on processed food nutritional content Develop demand for high-nutrition products

5. The Road Ahead

We believe that in the coming years governments around the world will come under increased pressure to engage far reaching reforms and secure one of their population's most basic needs. As experience builds, we believe one of three scenarios—or possibly a combination of these—will play out.

Status Quo

In the first scenario, a few governments engage several reforms to strengthen their food security and adapt their systems to climate change. While food is secured for several food items in these countries, severe disruptions occur as not all items are produced domestically, and increased investment is needed throughout the food supply chain. In addition, regional and international pressure from the countries which have not engaged these reforms will hike global food prices. Finally, the world sees an increasing amount of climate and food refugees that will increase pressure even from within the reforming countries as well.

Technological Revolution

In the second scenario, it is assumed that all countries have taken the measure of the weaknesses in their food systems and are ready to invest significantly to palliate them. All countries that have the financial means to acquire these technologies do so. High and medium income countries invest in all core aspects of their food security. Food security is ensured primarily through investments in climate-smart technologies, infrastructures and nudging food demand toward high-nutrition products. However, population growth and urbanization in low-income countries combined with the effect of climate change still lead to increasing global food prices as well as climate and food refugees.

Cooperation Revolution

In the third scenario, all assumptions from the second scenario still hold and increased regional and international cooperation in terms of investment and technology transfer is added. As a result, all spaces with high agricultural potential are exploited with more optimal technologies to maximize productivity and mitigate climate change effects. Investments in agricultural and food R&D witness an increased in their cost-benefit ratio as funding sources multiply and benefits are expanded all over the globe. While there are still climate and food refugees, their numbers are minimal and international cooperation enable their proper and adequate management.

Moving Forward, Governments Must Put Food Security at the Top of their Agenda

Food security is about more than production. It must be developed in all its aspects if it is to exist at all. Countries and cities must have a holistic approach when considering their food system from farm to fork and the interconnection of their national system to the world. We have already seen in the past 10 years the limitations of the current food system with disruptions becoming both more frequent and severe. One lesson is clear: reforms are needed and work ahead is considerable.

The 21st century will present considerable challenges for countries and cities to rise to. A surging global population, increased urbanization, aging population, shifting dietary patterns, and saturation and pollution of arable lands will require rapid and ambitious initiatives to shift away from the current status quo. All of this is taking place against a backdrop of what is likely to prove the most disruptive in the history of the planet: climate change.

Some countries and cities have already begun to adapt with government realizing the urgency of the matter if their population's most basic needs are to be met sustainably and durably. While no place starts with the same advantages or disadvantages, all must strive in the same direction and none can act on their own. Considering how our food system is reliant on trade, even net exporters rely on other countries.

Ambitious policies and entrepreneurial projects have paved the way for a set of enablers to be tested and assessed. Availability of food can for example be developed through the development of local production, an increase of domestic stocks for critical food items and diversification of imports. Physical access can be developed through improved infrastructure and cold chain network as well as regulation of retailers to minimize waste. Economic access can be promoted through mechanisms to mitigate price increase and support programs for vulnerable groups. Utilization can be strengthened through enhanced food safety standards, stricter nutrition regulations as well as the promotion of nutrition-rich products.

There is no one size fits all, but lessons learnt and best practices have been identified. It is only a matter of awareness and setting priorities. Several governments around the world are already hard at work. Cities that had been impacted by previous food crisis such as Singapore have sought to diversify their sources of imports. Others have heavily invested in new technologies such as vertical farming or greenhouses to increase their production output. Although efforts have been made, nothing can be done without increased investment in the agriculture sector and enabling technology transfer towards places with agricultural potential that lack the means to develop it. No stone can remain unturned in this context. One thing is certain, though: the time to begin is now.

Authors



Matthieu
De Clercq

Partner
matthieu.de.clercq@oliverwyman.com



Anshu
Vats

Partner
anshu.vats@oliverwyman.com



Alvaro
Biel

Engagement Manager
alvaro.biel@oliverwyman.com



Etienne
Raynaud

Senior Consultant
etienne.raynaud@oliverwyman.com

Contributor



Pawel
Zoltko

Associate
pawel.zoltko@oliverwyman.com



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