Future of food and farming

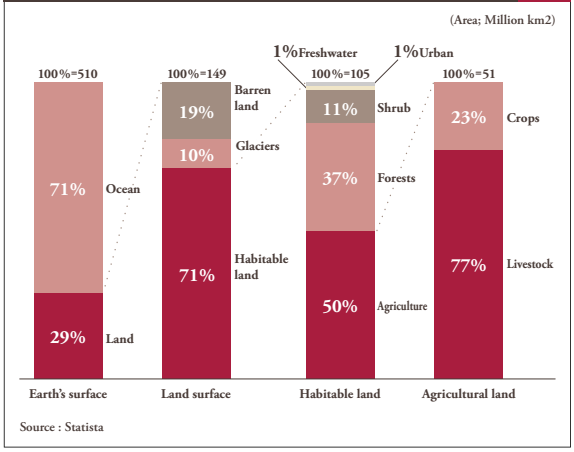
The population of the Earth has continued to increase since the Industrial Revolution. The world population will increase to 9.8 billion by 2050. For a sustainable world, what should we eat, where and how the food is grown?

Introduction

Can we feed the future generations?

By 2050 world population will increase to 10 billion people with 70% living in urban areas (up by 49 percent). Most of the population growth is expected to be in developing countries. To feed the future population, the overall food production has to be increased by around 70%. As per experts, by 2050 protein consumption is going to increase by 80%. With traditional farming, current land is not enough to produce enough meat for 10 billion people. So to increase the production, farming needs transformation.

Land usage statistics Chart 1



Source : Statista

In this paper, we have researched how the future farming will be transformed to satisfy the future food demand. As per our research, future farming will be driven by following factors;

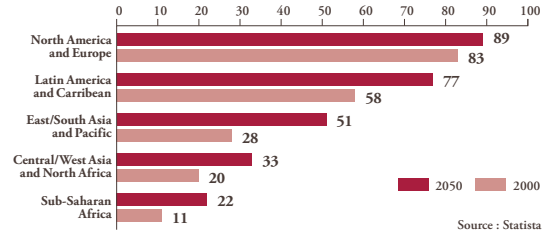
- New sources of proteins: Alternative proteins and bioengineered new food sources will become popular
- Technology innovations: Disruptive technologies will transform farming permanently for the good
- Demand for production near consumption: Food is produced nearer to consumer through urban farms

Driver 1: New sources of proteins

With majority of farmland used for livestock rearing and massive emissions of CO2 to produce meat, we don't have enough land and water to increase meat production using livestock. So it is necessary to identify new sources of proteins which are created in a more efficient manner.

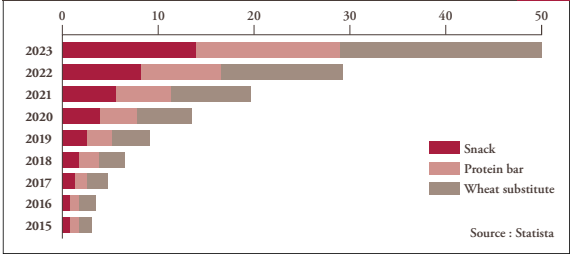
Below table lists down the new sources of proteins which consume less natural resources. Based on the source, the proteins are categorized into insects, cell, and plant.

Per capita consumption of meat in2000 and 2050 — Chart 2
Kilograms per person per year



Source : Statista

Food insect market value Forecast in the USA — Chart 3
USD millions



Source : Statista

New sources of proteins — Chart 4

New sources of proteins			Benefits	Startups	Key challenges
Mini livestock		Edible insects like crickets, grasshoppers, caterpillars, locusts, wasps etc	• Good amount of nutrition • Proteins produced at low cost • Less water consumption • Drastically reduced co2 footprint • Around 91000 species	• EXO, USA • Chirps Chips, USA • Bitty Foods, USA	• Public acceptance
Clean meat (also known as lab grown meat, cultured meat)		Grown from animal cells without slaughtering animals	• Earth friendly(less usage of ene rgy, water and land. Reduction in greenhouse emissions and wastage) • Safe from diseases, chemicals • Less food inputs	• Memphis Meats, USA • Mosameat, Netherlands • SuperMeat, Israel	• Public acceptance • Scaling up production • Cost reduction • Serum free media • Structure
Plant based	Non-dairy milk	Dairy products produced from plants	• Low sugar • High calcium • Low fat • Cholesterol free	• Ripple Foods, USA • Good Karma Foods, USA	
	Drink meals	Drink made from plant based proteins	• Less water • Low co2 emissions • Long shelf life	• Soylent, USA • Super body fuel, USA	
	Meat	Mock meat made mainly using plant ingredients	• Antibiotic free • Hormone free • Gmo free • Gluten free	• Impossible foods, USA • Beyond meat, USA	
Fungi		Mushroom based proteins	• Improves taste of food • Low in calories, fats and carbohydrates • Loaded with vitamins and minerals • Organic	• MycoTechnology, USA • Terramino foods, USA	
		Real milk generated from yeast and fermentation techniques	• High nutrition • Free from hormones and antibiotics • Earth friendly (less usage of energy, water and land. Reduction in greenhouse emissions) • Lactose free • Cholesterol free • Long shelf life	• Perfect day foods, USA	• Public acceptance • Regulation hurdle to label as non-gmo food due to the usage of gmo in the production process.
Algae		Seaweed	• Good amount of nutrition • Grows faster	• Algama, France	• Regulations
		Shrimp made from algae and plants	• Good amount of nutrition • Grows faster	• New wave foods, USA	• Imitate shrimp texture for mainstream acceptance

Edible insects as proteins

Consumption of edible insects is not new to some cultures. Historically insects are part of daily food in some cultures. For example, countries in Africa and South East Asia insects are consumed for many generations. Insects like crickets, grasshoppers, caterpillars, locusts, wasps etc. are a good source of proteins because of high nutritional quality and low natural resource utilization. For example, to produce one gram of protein, insect farming require 18 square meter compared to cow farming which requires 254 square meters. However, it has its own challenges. Will public be ready to see insects on plate? To resolve this issue, some startups are converting insects into protein powder and selling as proteins bars, proteins ingredients etc.

Clean meat

Due to growing interest in clean meat, we would like to discuss more on clean meat in this section. As per good food institute, clean meat is genuine animal meat that can replicate the sensory and nutritional profile of conventionally produced meat because it's comprised of the same cell types arranged in the same three-dimensional structure as animal muscle tissue. Also clean meat is not genetically modified. The production of clean meat begins by incubating stem cells in a media that is rich in nutrients that help the cells grow and divide, while using scaffolds and other technological aids that eventually lead to the creation of a thin layer of muscle tissue that is the edible product.

Advantages 1: Environment friendly

Clean meat will have a much smaller eco footprint requiring 99% less land, up to 96% less greenhouse gas emissions and up to 90% less water usage.

Advantages 2: Animal welfare

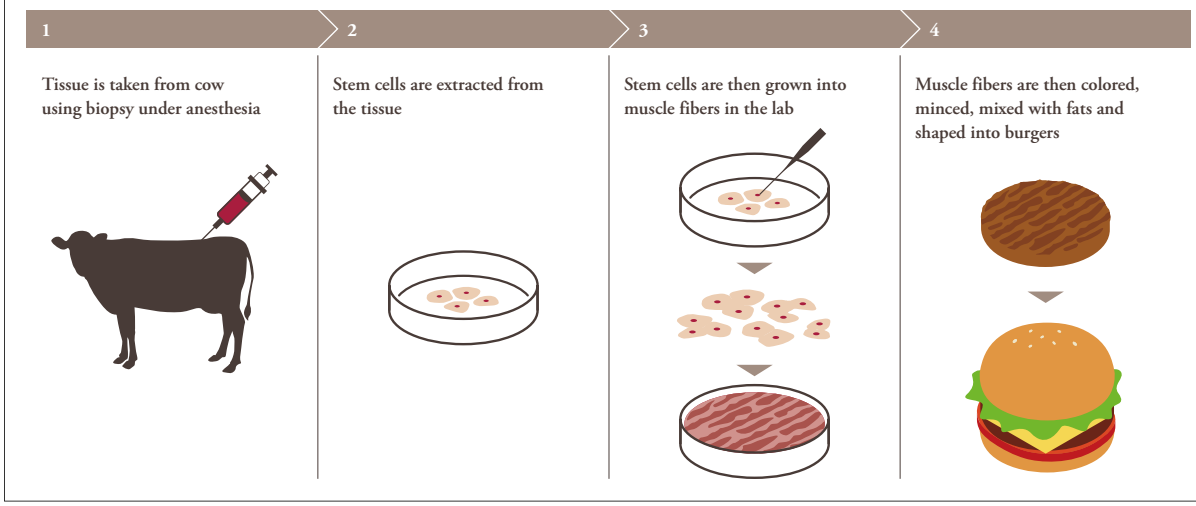
Not even a single cow will be slaughtered to produce clean meat. Also a single biopsy will allow producing enough meat to make tens of thousands of hamburgers. However, currently animal serum is used as feed to the cells. But in near future they will be replaced by plant based serum.

A major clean meat company CEO says "Tens of Billions of chicken are being slaughtered annually around the world which can be totally eliminated by embracing clean meat. By maintaining a cell bank, we don't need chickens anymore for making clean meat".

Advantages 3: Healthier

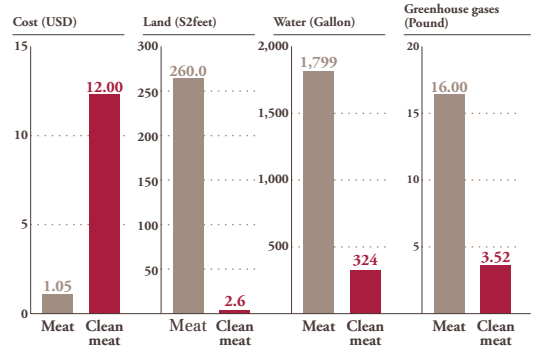
Clean meat is produced under controlled and clean conditions. Due to clean environment, there is no need to use antibiotics. This will eliminate the food-borne diseases, bacterial resistance and much more.

How the burgers are grown with clean meat — Chart 5



Clean meat is free from artificial growth hormones which are usually used in livestock for faster growth. Clean meat has no genetic modifications. Also clean meat can be more nutritious than traditional meat due to the nutritious feed. According to Ido, CEO of SuperMeat, due to contamination-free production environment, clean meat has longer shelf life than traditional meat.

Meat vs. clean meat — Chart 6



Source : CB insights

Future value chain of clean meat

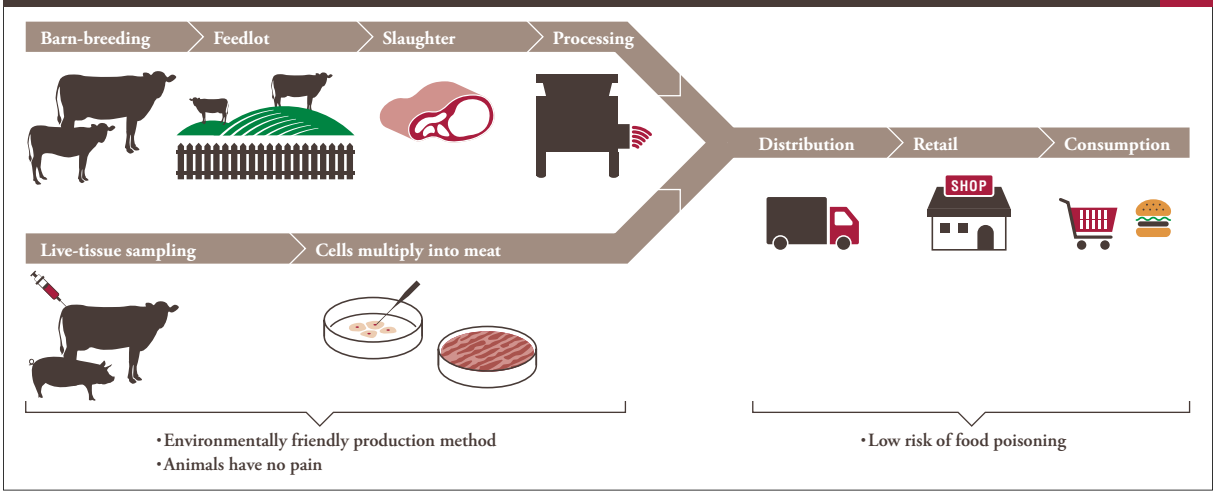
Compared to traditional meat, clean meat removes/adds/scale down some steps in the value chain. For example, clean meat value chain will not have steps like breeding, raising, slaughter, processing etc but will have steps like feed supply chain, cell proliferation etc. In addition, the clean meat value chain will scale down required number of livestock drastically.

Clean meat is a trillion dollar industry. Clean meat has lot of opportunity to gain the market share. Gaining a 10% market share will be around USD 100 billion. Currently the number of companies in clean meat is in single digits. No wonder in coming years, there will be multiple startups entering into this industry.

Impact on traditional livestock farmers

A large acceptance of clean meat will have a major impact on traditional meat industry. Due to scale of economy, clean meat becomes cheaper than traditional meat and there will be drop in demand for traditional meat. However, there will still be demand for premium traditional meat like Kobe beef, Matsuzaka beef etc. but not enough to cover the losses. This will create job losses in the industry. Although it will take 10 to 20 years for clean meat to become a mass market, but it is necessary to start thinking how the unemployed traditional farmers will be supported. Recently, discussion has started in Silicon Valley on universal basic income to support people who are going to lose jobs in near future due to automation. Something similar has to be introduced in traditional meat industry. In addition to universal basic income, traditional meat industry farmers can think of job shift to clean meat industry. Clean meat industry is going to create new jobs in new areas like nutrition supply for growing clean meat.

Our meatless future — Chart 7



According to Ido, there is enough time for traditional meat farmers to transform like producing high end premium meat where there will still be demand, make bio factories to produce clean meat cells, produce media for clean meat etc.

However such job shift requires skill development. To reduce unemployment, countries which are hugely dependent on traditional meat industry should start planning the transition before it is too late.

Challenge 1: Public acceptance

It is no wonder that convincing public to eat clean meat will be a major challenge. Similar to genetically modified food, clean meat will face resistance from multiple quarters. It is necessary for clean meat companies to work with governments and non-profit organizations to increase the awareness of clean meat. They should clearly explain the pros and cons of clean meat and leave it to the consumer to decide. Consumers should have the option to choose. Forcing the consumer to shift faster to clean meat will backfire. Similar to café, where you have an option to choose between cow milk and soy milk, consumers should have the option to choose between traditional meat and clean meat.

According to Ido one approach for public acceptance of clean meat is to make everything transparent by talking with public early. He is thinking of creating a facility in urban areas where public can see how safe is the production process is and also taste the clean meat.

Challenge 2: Scalability

Due to nonexistence of growth medium (the feed for the cells) operations, it will take a while to become scalable. The supply chain complexity depends on the complexity of the growth medium. As per CEO of Mosa Meat Mr. Peter Verstrate said “mass retail (supermarkets) will take at least 10 years. Up-scaling of feed production is the main driver for getting to actual mass market”

Challenge 3: Cost reduction

According to Ido, industry has proven that clean meat tastes similar to traditional meat. Now it is time to create a cost efficient production to reach price parity of traditional meat. He also says most of the infrastructure required for producing clean meat is already present in pharmaceutical industry but at a small scale. What is required is to make the infrastructure scalable with low maintenance costs.

Currently clean meat is very costly compared to traditional meat. To make it a mass product, it is necessary to bring the costs to the same level as traditional meat. Peter Verstrate says “80% of the costs will be determined by the price of the feed”. So it has to be determined if the costs of feed can be brought down.

Challenge 4: Quality of the serum

Currently animal based serum is used to grow the cells. It will be very challenging to make plant based serum with the same nutrition as animal based serum. Also will the plant based serum be organic? Does creating clean meat in lab have a possibility of introducing new type of diseases? Animals have developed immune system from many generations. So the immune system still works in the lab has to be confirmed.

Challenge 5: Regulation

It should be seen how the clean meat industry will be regulated. Will the name will be clean meat or lab grown meat or something else? Will the regulations be same as traditional meat or pharmaceutical industry?

According to Ido, due to similarity in nature of production for insulin and clean meat, existing FDA regulation infrastructure for insulin will be quite enough to regulate the R&D of clean meat.

Driver2: Technology innovations in farming

More than price, consumers are concerned on health of the family and planet. Consumers want to know more about the food they are consuming like how it is made, whether it is organic, animal welfare, environment friendly, healthier etc. Growing consumer interest in clean meat, plant based meat, non-dairy products etc. shows loss of trust in

Technology application in food value chain

Chart 8

Value Chain	Company name	Technology Applications	Outcome
Input	·Moocall(USA)	·Monitoring delivery of domestic animals: Sensors are attached to pregnant cattle's neck, ears, feet, tail and so on. Alert is sent before parturition	·Reduce mortality rate of cattle during labor
	·FlyBird Farm Innovations(India)	·Irrigation control system: Automatically supply water etc. according to soil condition using humidity / temperature sensors	·Improvement of crop yield and 20% -30% reduction in water usage
	·Cropital(India)、iGrow(Indonesia)	·Agricultural Crowd Funding: With the crowd-funding platform, farmers can connect with investors at a low cost	·Improve farmers' financing
	·Mimosa Technology(Vietnam)	·Schedule optimization of water and electricity usage: Collect soil condition data from sensor and accurately predict irrigation schedule	·25% improvement in crop yield and 30% saving in water and electricity consumption
Production	·VineView(North America)	·Drone and algorithm analysis: Detect diseases in vineyards from the air using drone-based sensors and advanced algorithms	·Avoid losses of $40,000 per hectare in vineyards
	·eFishery(Indonesia)	·Automatic feeding system: Attach a vibration based sensor to aquarium tank, read the movement of fish, measure fish's appetite from the aggressiveness of movement and accordingly adjust the amount of food	·Improve Feed Conversion Ratio by 21%
	·Tevatronic(Israel)	·Autonomous irrigation system: Fully automated farm irrigation and fertilization by utilizing sensor / cloud technology (different from automatic + decision support irrigation system)	·2-29% yield increase and 5-74% reduction in water and fertilizer usage
	·VISION ROBOTICS (USA)	·Advanced robot technology: Developed a robot that understands the situation and can work even in a realistic environment	·Expansion in mechanization of agriculture
	·Handsfree Hectare(UK)	·Remote agriculture: Develop automatic machinery for remotely raising crops even if there are no farmers in agricultural machine's driver's seat or plantation	·Improve yield by realizing fully automated farming
	·Agronow(Brazil)	·Risk calculation using deep learning technology: Deep learning analysis of productivity data around the world. Aims to make insurance company's decision more quickly and accurately	·Based on risk calculation, Insurance companies decide premiums
	·Scicrop(Brazil)	·Smart Agricultural Platform: To enable the collection and analysis of real-time data on climate, soil, agriculture, pests & diseases, logistics, markets by providing big data analysis on smart farm integration platform	·Improve crop harvesting efficiency
	·AGRIBELA(Brazil)	·Pest control drone: "Biodrop" a combination of AI, drones and wasps. AI drops the wasps using drones to hunt the pests	·Able to realize 90% pest decrease without using pesticides
Processing and Distribution	·ermoPLEX(Brazil)	·Grain storage system: Measure temperature and humidity inside the silo with a sensor and automatically keep the temperature suitable for storage	·15% to 100% of reduction in food storage losses and up to 60% of energy savings
	·Crofarm(India)	·Supply chain management: Provide a platform to connect customers and farmers, consolidate supply and demand	·Increase in farmer income by reducing agricultural wastage
Consumption	·Natural Machines(Spain)	·3D print of foods: Put food in paste form into a special capsule, adjust the flavor / sweetness, etc. and cook food with 3D printing technology	·Shortening of cooking time, various designs
	·CITYFARM(Malaysia)	·Hydroponic cultivation: Provide know-how on hydroponic cultivation, equipment and fertilizer etc. to those who want to become "urban farmers"	·Create Sustainable city by local production
	·TE-FOOD(Germany)	·Food traceability: Visualize food traceability to all stakeholders of the food supply chain with block chain technology	·Consumer safety, farmer trust, and elimination of inefficiency in supply chain

traditional way of growing food. The income levels of the consumer will also play a role in the food choice. High income people will go with natural food, while lower income people go with cheaper one.

So it is necessary for players in the food industry to make the industry more efficient, environment friendly, more natural food, animal friendly, healthier and transparent to the society.

In this section, we would like to share how technology can be used to satisfy the expectations of the society.

Chart 8 shows, the application of technology in food industry. The farmers who automate successfully will have the option to live in cities and monitor their farms remotely. Also it is inevitable that automation in farming will result in job losses. The job losses will be high in developing countries where many people are dependent on farming. But at the same time, automation of farming will create new jobs. It needs to be seen how the transformation will be. Most probably government in developing countries will start universal basic income for farmers who lost jobs due to automation

Driver3: New demand
- Urban farms -

Urban farming is the practice of producing food and medicine in vertically stacked layers, vertically inclined surfaces and/or integrated in other structures (such as in a skyscraper, used warehouse, or shipping container). Due to controlled environment, urban farms can grow more crops at a faster rate than traditional farms or greenhouse with less consumption of resources like water. There are benefits as follows;

- Consume less amount of water, land, fertilizers and logistics than traditional agriculture and greenhouses
- Pesticide free

- Low labor costs due to automation
- Can be setup anywhere like buildings, supermarkets, hotels, community facilities etc.

Challenge 1: Consumer behavior

Consumers pay premium only if there is a big differentiation. So it is necessary for vertical farming to differentiate from traditional greenhouse. Currently the major differentiation is high degree of freshness and variety which is quite attractive for restaurants.

Challenge 2: Costs

Vertical farms have lot of extra costs compared to traditional and greenhouses initial costs such as structuring, IT, CO2 machine, air conditioning, germination chamber, dehumidifier etc. and operation costs such as energy, rental, labor, good seeds/nutrients etc. As per Stephen vice president of Alesca life, energy occupies more than 60% of the opex. So it is very important to consider reducing the energy costs by using renewable energy, sun light etc.

Challenge 3: Location

Although in future the food is grown nearer to consumer but as per experts in some cases growing nearer to consumer may not be possible due to various reasons.

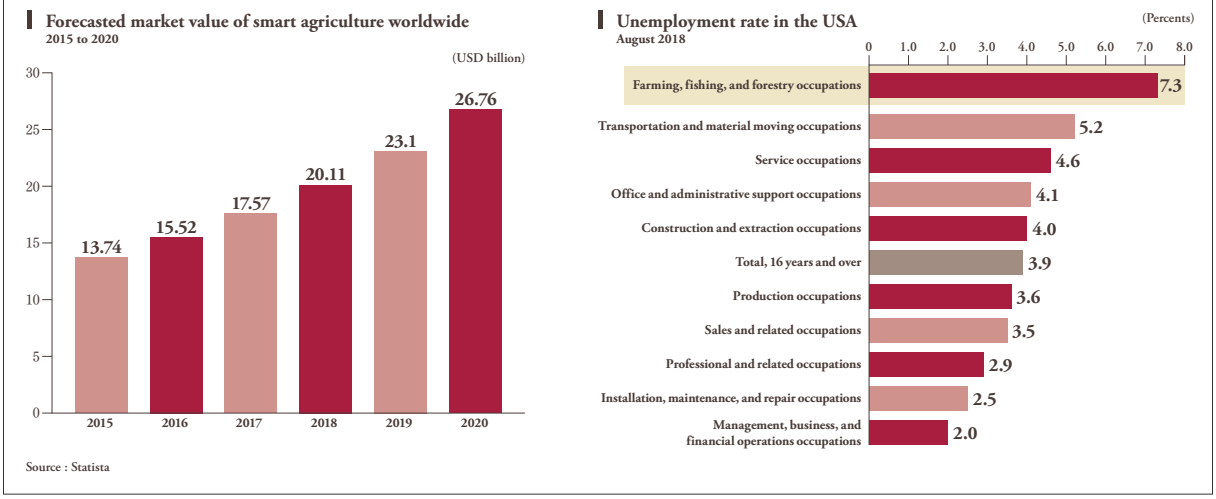
As per a mushroom farmer, it is difficult to grow mushrooms in vertical farms near to consumers due to the release of carbon dioxide (CO2), strong odor, health concerns etc.

Vertical farming makes sense in countries like Japan, Singapore, Gulf etc. where the land is scarce or traditional agriculture is not sustainable. However in countries like Brazil, USA etc. where there is lot of land, vertical farming may not be effective. As per a farmer in Brazil, they never thought of vertical farming as they have lot of land to feed the population. However they have to bear in mind the logistics costs when they supply too far away countries.

Future image of food and farming

Based on above three drivers, i.e. new sources of proteins, technology innovations and demand for locally produced food, the conceptual image of food and farming in future will be as follows where the renewable energy, rain water etc. will be used to grow food. Consumers will have more food options. More food is made nearer to consumption like retailers will have the option to make meat in-house, clean meat companies will be making meat at a locality level etc. Time will come where farm is no more outside the city. At the same time, traditional farming will be more automated with efficient supply chain. In the end, it is the consumer who decides what to eat from those options.

Smart agriculture market value and unemployment rate — Chart 9



Source : Statista

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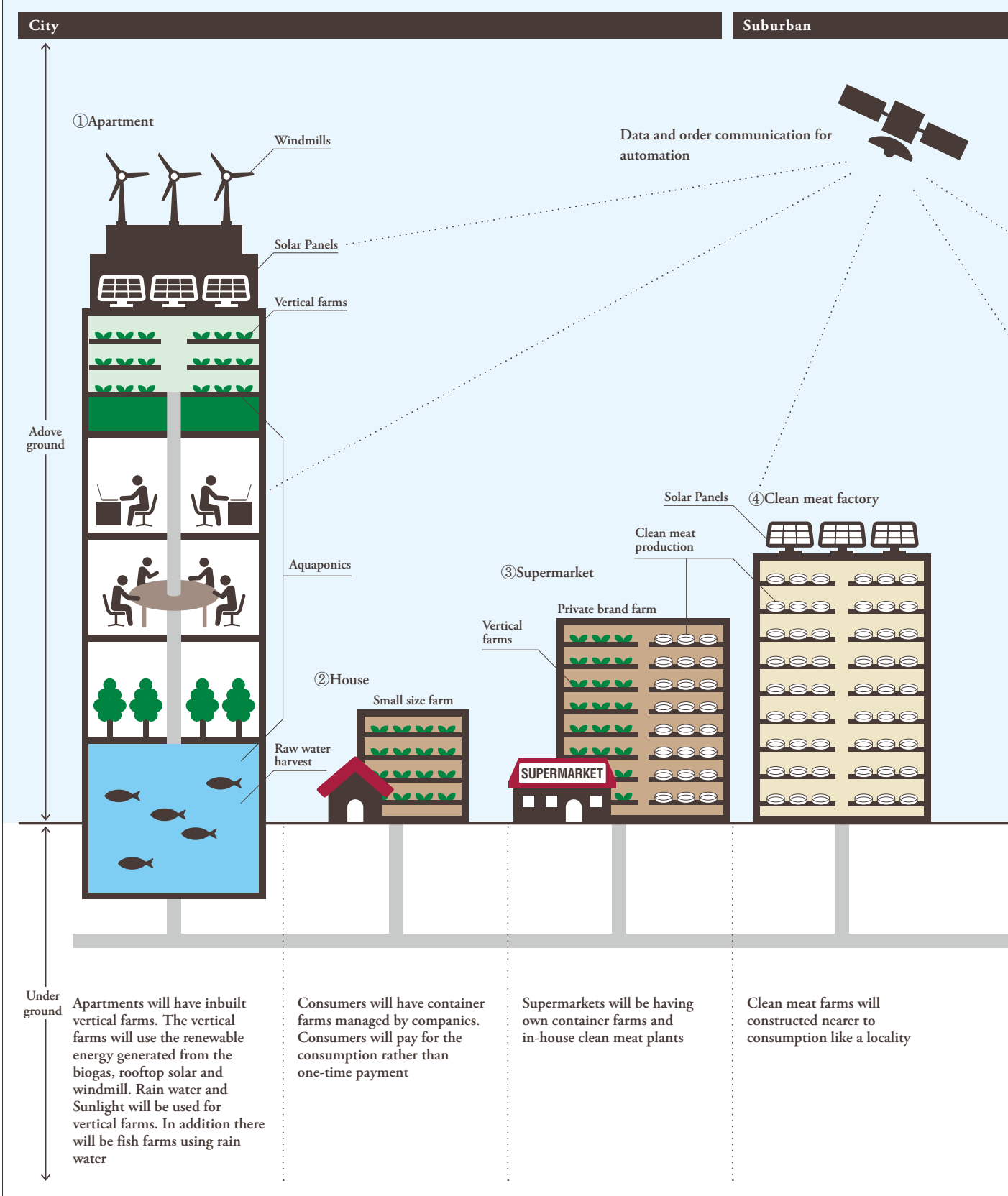
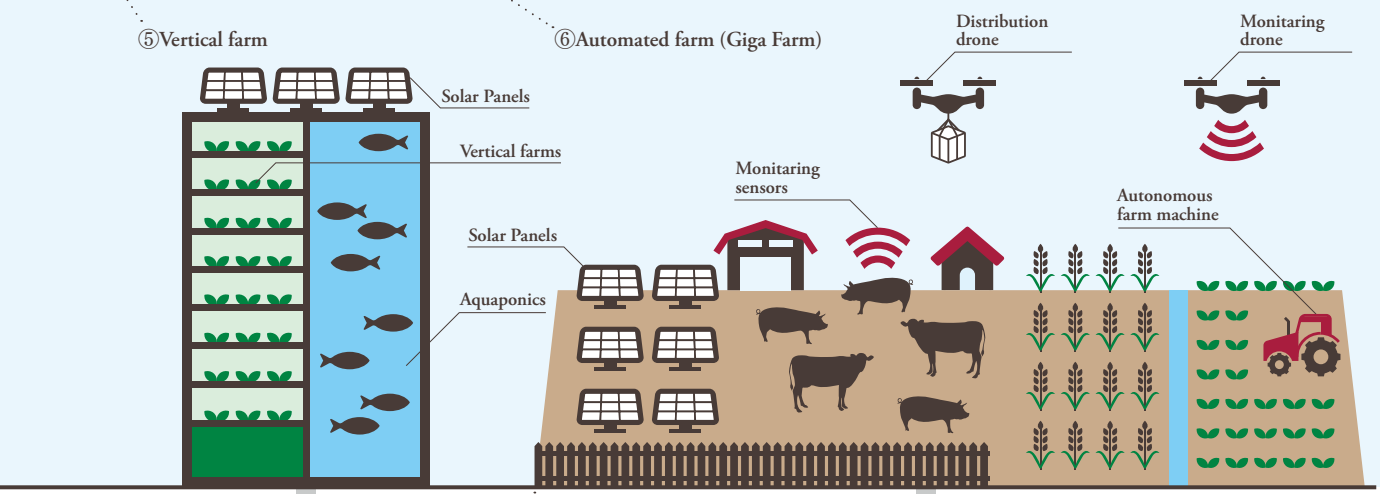
Future Smart Farms



Rural



Huge Vertical farms will constructed nearer to consumption

Rural farms will be more automated with farmers remotely monitoring the crops

- Farming will be done based on scientific methods rather than traditional. More data is stored in cloud and management. Digital farms are created to simulate the crops
- Livestock is monitored for diseases, birth etc and alerts are sent accordingly to farmers, veterinary etc.
- Farming equipment like tractors is automated and controlled remotely
- Drones are used to survey the fields, mapping, diseases, spraying etc.