# FUTURE FOOD

Climate change and sustainability pose significant challenges to food production as we attempt to keep our ever-growing population fed, while limiting its environmental impact. Consequently, we are having to find new and inventive ways to produce and manufacture our food as well as revising some of our eating habits. To achieve this, however, requires novel technologies and food sources to create and maintain more sustainable food systems.

This infographic will explore the problems in supplying a growing population with food and the solutions being developed to overcome the issues.

# THE PROBLEM

It's estimated that there will be nearly 10 billion people on the planet by 2050, requiring around a 70% increase in food production to sustain them.

NEARLY

# 1 in 3

**PEOPLE IN THE WORLD**

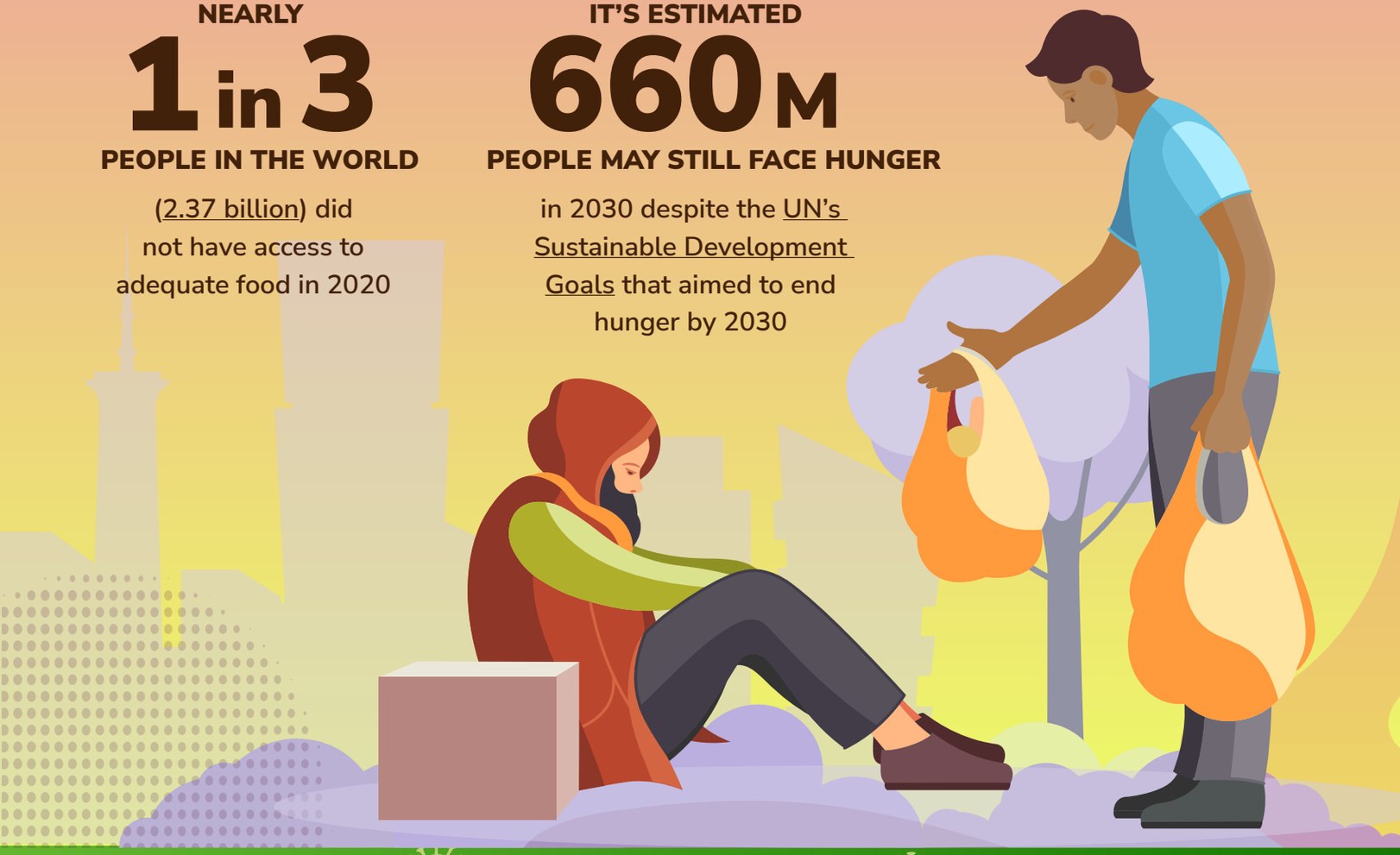
(2.37 billion) did not have access to adequate food in 2020

IT'S ESTIMATED

# 660 M

**PEOPLE MAY STILL FACE HUNGER**

in 2030 despite the UN's Sustainable Development Goals that aimed to end hunger by 2030



While the lasting effects of the COVID-19 pandemic play some part in this stark reality, a food system unable to cope with the population is the underlying issue.

Our planet too is suffering as a result of our food eating habits and agricultural practices.

**FOOD PRODUCTION IS RESPONSIBLE FOR APPROXIMATELY**

# 25%

**OF THE GREENHOUSE GASES**

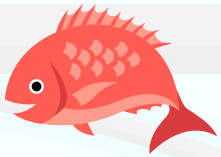
emitted annually, with half (mostly in the form of methane) thought to come from animal farming.

Agricultural ammonia, mostly generated by livestock farming, is an important source of harmful particulate **AIR POLLUTION.**

With **WATER** a limited and valuable resource in many areas, the amount needed to produce our food is worth considering.

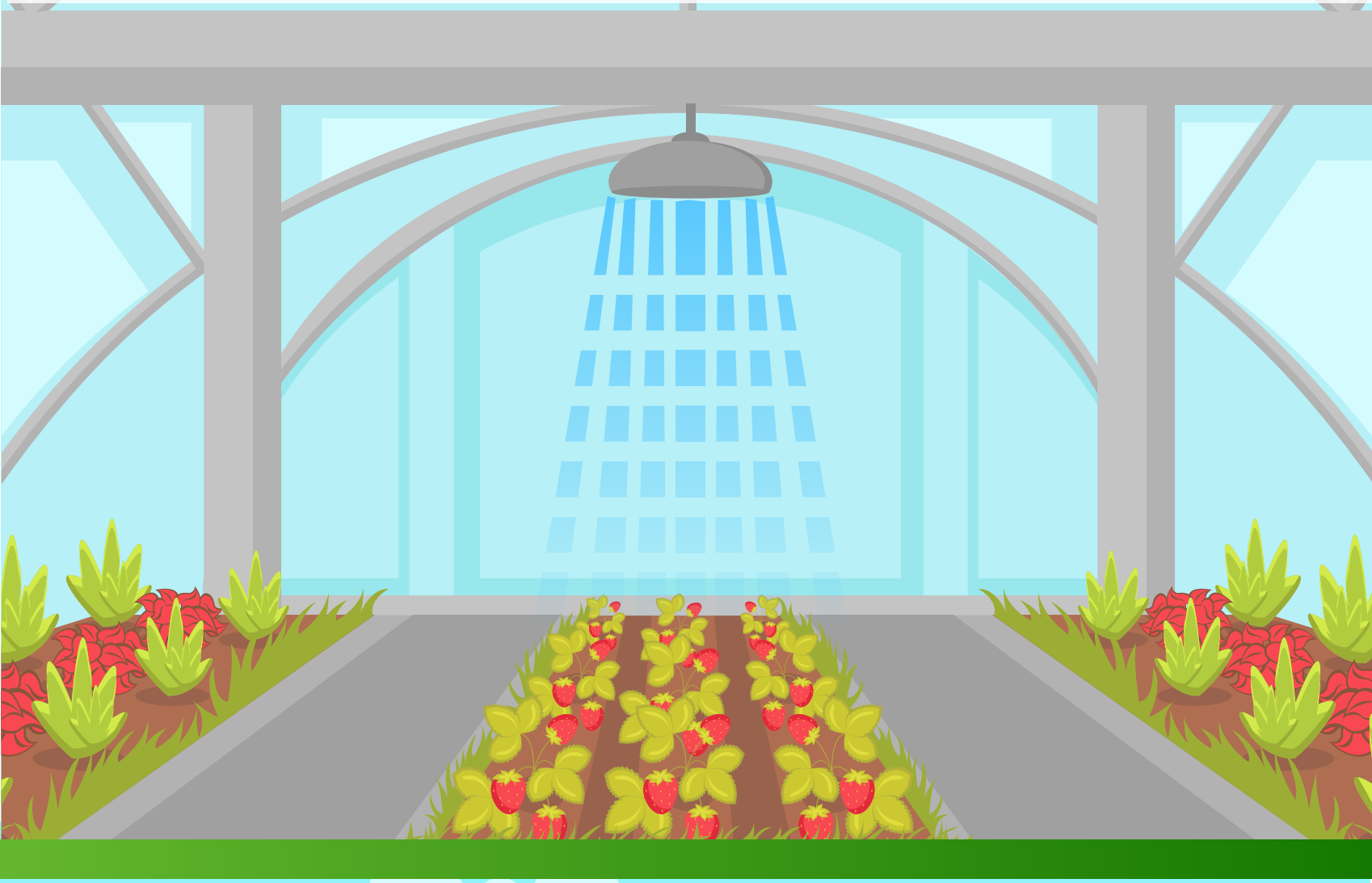
**3,413** LITERS

of freshwater withdrawals are needed per 1000 kcal to produce farmed prawns

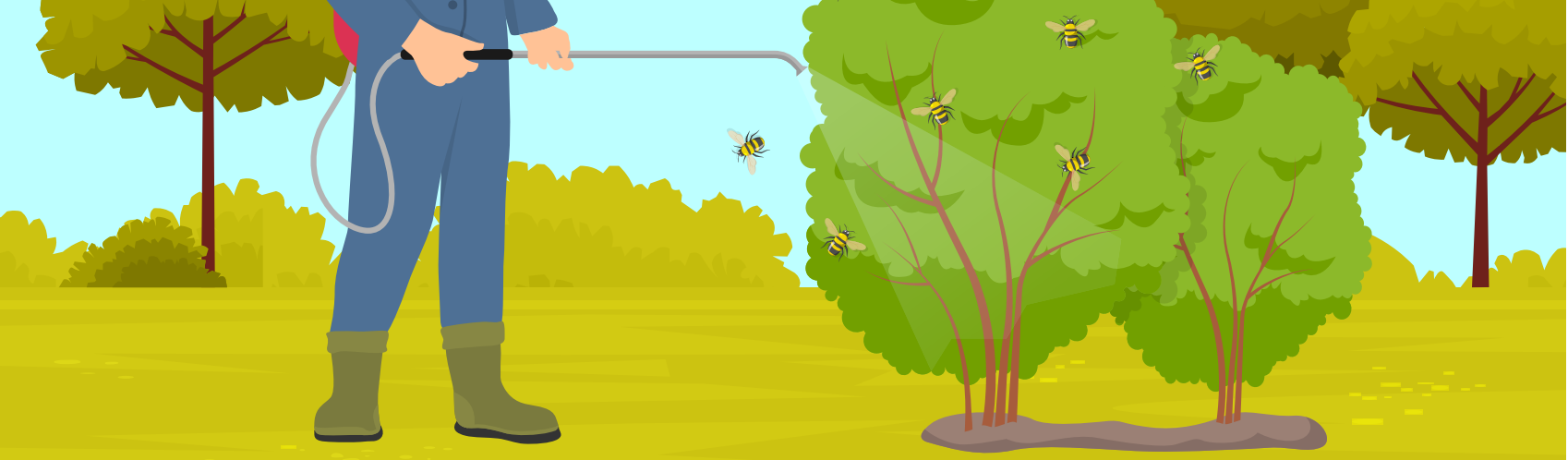


**2,062** LITERS

for farmed fish compared to just **55** liters for soyabeans and **3** for barley!



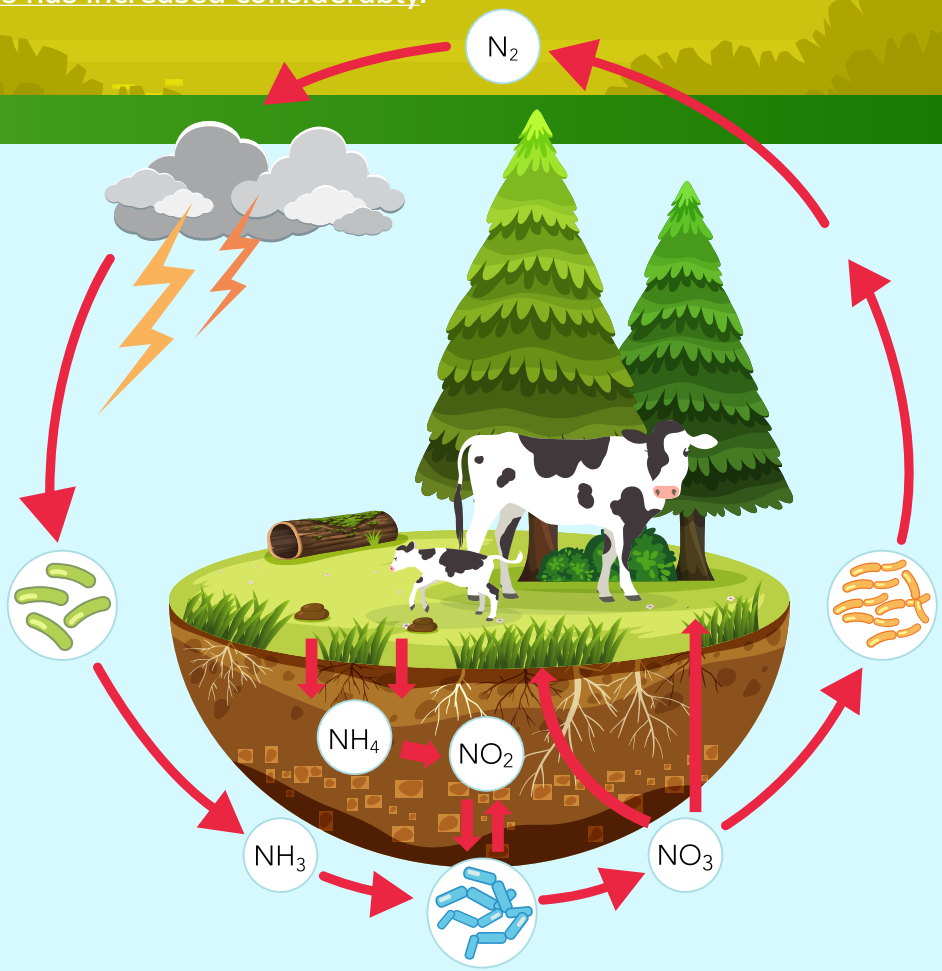
While **PESTICIDES** help to protect our food and animal feed crops and keep our livestock healthy, they can be harmful to off-target species and disrupt food webs.



Evidence suggests that, while toxicity to birds and mammals and the applied amounts of pesticides such as neonicotinoids have reduced, the toxicity of insecticides to aquatic invertebrates and pollinators has increased considerably.

**EUTROPHICATION**—the pollution of habitats, in particular water, with excess nutrients such as nitrogen—is a major problem, polluting ecosystems and causing nutrient imbalances. Runoffs from agricultural production, including fertilizers and animal waste, are a significant contributor.

Per kg of food product (milk), dairy cattle produce 365.29 g of eutrophying emissions (phosphate equivalents).




Around half of the habitable **LAND** on Earth is now used for agriculture. Disproportionately, **77%** of this is accounted for by livestock rearing, be it pastureland or land used to grow animal feed.

This puts further pressure on habitats and ecosystems and endangers species of animal and plant life. Of the more than **40,000 species classed** as threatened with extinction on the IUCN red list, agriculture or aquaculture are listed as a threat for over **21,000 of them**.

It's not just production either. **FOOD WASTE** is estimated to produce 4.4 $GtCO_2$ eq, or about 8% of total anthropogenic greenhouse gas emissions every year, contributing to climate change. Food waste would be the third largest emitter after the US and China if it was a country.

And that's aside from emissions related to packaging, storage and distribution.

Due to their population densities, while they only occupy around 3% of land,

CITIES ACCOUNT FOR

# 70-80%

OF THE WORLD'S POST-CONSUMPTION FOOD WASTE

Tackling waste at this point in the process is therefore important as well as wastage during production, processing and retail.

IN 2019, AN ESTIMATED

**931** MILLION

METRIC TONS OF FOOD,

equating to 17% of the total food available to consumers, went into the waste bins of households, retailers, restaurants and other food services.

Fruit and vegetables (**39% of total wastage**) followed by dairy (**17%**) and then meat (**14%**) are the most wasted food groups.

A recent study indicated that meat consumption would need to fall by **75%**, ideally, for planet Earth to continue feeding us in the future.

**PROTEINS** form an important part of a balanced diet, so simply cutting them out is not an option. We get our protein from foods like meat, fish, eggs, dairy products, beans and pulses and nuts and seeds. Therefore, finding sustainable solutions to our food and protein supply issue is of paramount importance.

# THE SOLUTION

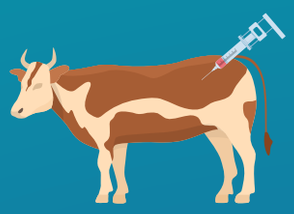
There are a variety of ways in which researchers are trying to address these problems. These include looking for alternatives to foods that have the biggest environmental impact, changing production methods, reducing waste and trying to popularize foods that we may have shunned entirely. Let's look at some strategies showing the most promise.

## CELLULAR AGRICULTURE

The idea of having animal products without the animal may sounds bizarre but that's exactly what cellular agriculture is striving for.

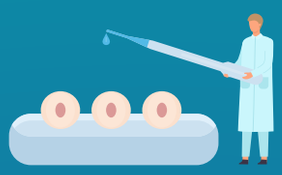
The desired cells, often stem cells that can be differentiated to become muscle, fat or connective tissue, are:

**1**



**Taken from an animal...**

**2**



**...and cultured in the lab.**

**3**

**Once scientists have a cell line they are happy with, the culture can be scaled up...**

**4**

**...towards creating a food product.**

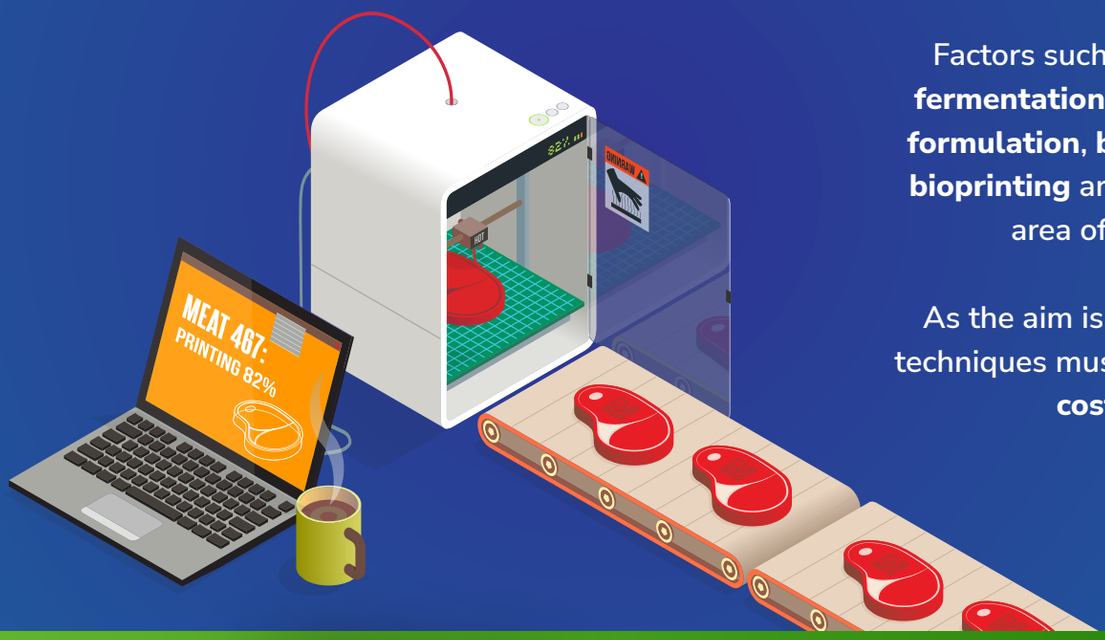
This also offers the opportunity to engineer the cells used for the culture to **enhance the nutritional value** of the "meat" produced. Scientists engineered bovine cells to produce the dietary antioxidant carotenoids phytoene, lycopene and β-carotene. Techniques like this could provide consumers with nutritional benefits or aid those with deficient diets. As they are grown in culture, it also means undesirable traits such as cholesterol or microplastics will be absent.

**While scientists have been culturing cells for many years, creating something that you may want to eat is another matter.**

With an animal, tissues are interwoven by blood vessels that provide **everything needed for growth** and **remove waste**. They also have structural materials that give them **shape** and **texture**, which are absent in a basic cell culture. Therefore, the cultured cells must be provided with a scaffold to grow on and liquid media to nourish them. Stable conditions in the form of a bioreactor then provide them with the temperature, pressure etc. for optimal growth.

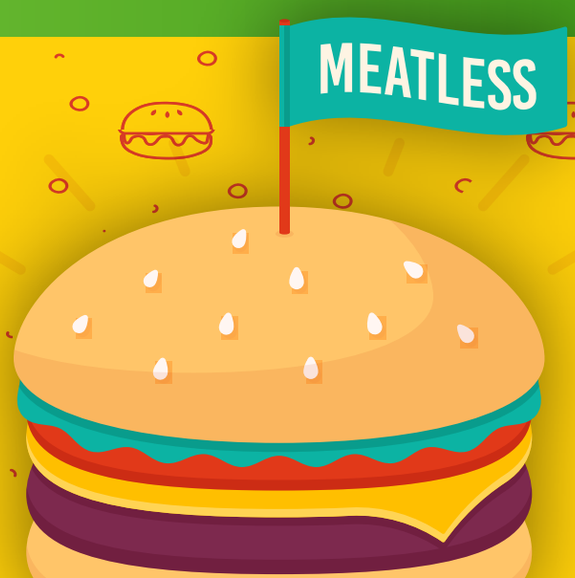
The type of **scaffolding** is also important in getting the texture right and must be safe to eat.

The addition of the iron-carrying blood and muscle proteins **hemoglobin** and **myoglobin** have also been explored and found to **improve cell growth and "meat" texture and color.** This aids production and helps to improve consumer acceptance.




Factors such as **cell scaffolding**, **fermentation technologies**, **media formulation**, **bioreactor design** and **bioprinting** are therefore key in this area of development.

As the aim is food production, the techniques must also be **scalable** and **cost-effective**.




In 2013, a burger made via cell culture cost € 250,000. Since then, costs have plummeted.

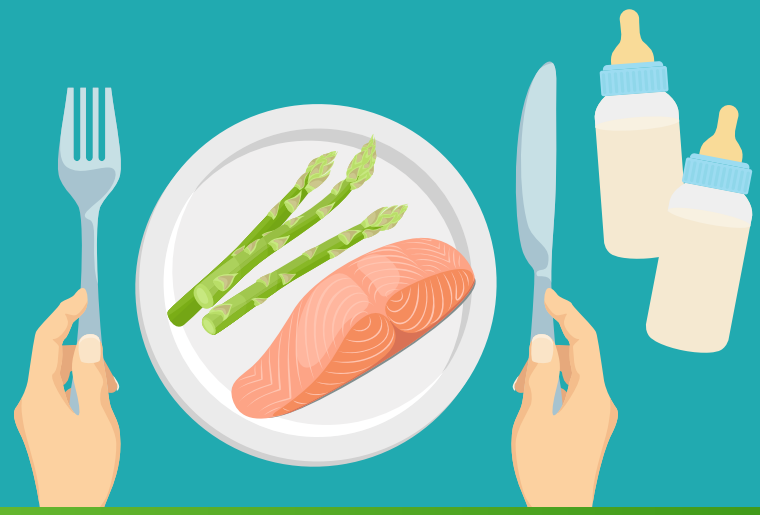
**DATA INDICATES THAT CONSUMING CULTURED MEAT INSTEAD OF ANIMAL-BASED MEAT WOULD:**

REQUIRE **99%** LESS LAND

REQUIRE **96%** LESS WATER

PRODUCE **96%** FEWER GREENHOUSE

Unlike cattle ranching, cell culture facilities can increase capacity by expanding vertically, helping to alleviate land-use pressures.



Seafood and egg white are also being produced via cellular agriculture. In other cases, it may not be the cells themselves we are after but what they produce. Human and cows' milk have now been produced successfully this way too.

While for some, lab-grown meat and animal products are a step too far, others appear to be embracing the concept. It offers an option to those that want to help the planet without turning to veganism and are nutritionally equivalent to, or maybe even better than, their animal-grown counterparts. There is, however, still concern about the **socio-economic impact** a move from traditional farming may have and whether cellular agriculture can affordably deliver on its promises.

# FERMENTATION

Precision fermentation can be used to produce animal proteins, such as the cows' milk proteins casein and whey, from engineered microorganisms. Rennet for cheese making has been produced this way for decades.

**1**

**Genes encoding the desired protein are engineered into host organisms (usually bacteria, yeast or fungi).**

**2**

**These are cultivated in fermentation tanks, producing large amounts of the desired protein.**

**3**

**The protein is then separated from the host cells and purified for use in foods.**

# PLANT-BASED ALTERNATIVES

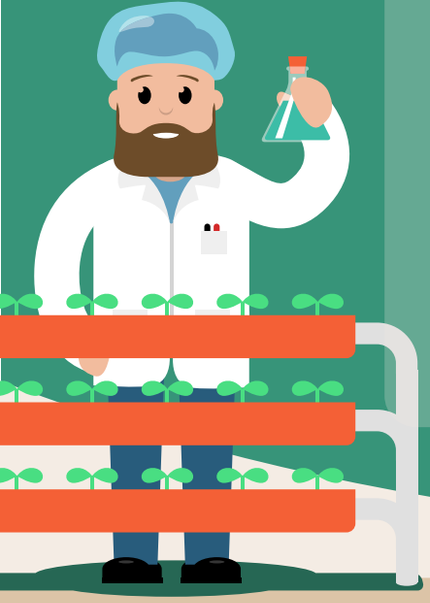
Plant-based foods are by no means free from environmental impact, but a recent study showed that of the greenhouse gas emissions related to food-based agriculture, plant-based foods contributed 29%, compared to 57% from animal-based foods. Therefore, switching out some animal-based products could bring significant benefits.

Vegetarianism and veganism aren't new concepts, and neither is creating plant-based versions of "meat-like" foods. However, researchers are making great progress in taking some of the characteristics that we love in animal-based products and recreating them in plant-based alternatives.

Factors such as **TEXTURE**, **COLOR** and **AROMA** are all important when creating a food people want to eat. Even if a product tastes good, if it doesn't have an appealing smell and appearance and the right mouthfeel, chewiness and juiciness, consumers won't buy it.

Recreating the stringiness of melted cheese, the juiciness of a steak or the texture of pulled meat is no small task. Manufacturers and developers have gone to great lengths to make plant-based "meat" as meaty as possible, including:

- Adding beetroot, berry and carrot extracts and leghemoglobin,



an iron-carrying molecule from soy, to simulate bloodiness and impart a meat-like flavor profile

- Adding indigestible fibers, like methyl cellulose or carrageenan, to thicken the texture
- Developing extrudable fat to provide marbling and juiciness and enable the saturated fat content currently relied on to be reduced
- Using isolated plant proteins to increase protein content
- Adding vitamin B12 and zinc to replicate meat's nutrition

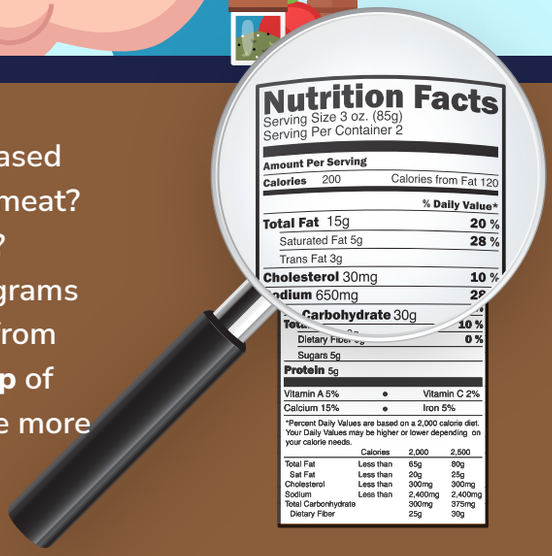
Prolamin technology is also helping to create cheese that melts, bubbles and stretches like the real thing.

Scientists have even been working to create 3D printable plant alternatives.

Techniques such as small angle X-ray scattering (SAXS) are helping researchers to understand and improve food characteristics at the nano level.

When meat is cooked, it releases hundreds of volatile compounds that we associate with that "meat" smell. The problem with plant-based alternatives is that they also release volatiles, just not ones we associate with meat. Some producers try to cover this with heavy seasoning but scientists are looking at ways to address this aroma profile problem.

Then there's also the **NUTRITIONAL** aspect. Do plant-based alternatives supply us with as much digestible protein as meat? Is it of the same quality? What about micronutrients? Packaging often expresses protein content generically in grams which can be misleading as we require the amino acids from those proteins. The **digestibility** and **amino acid makeup** of those proteins may vary, meaning some protein sources are more valuable to us than others.



A recent study looked at the **protein quality** of pork and beef burgers in comparison to some popular soy- and pea-based burgers and found that the plant-based burgers did not deliver the same level of digestible amino acids as the meat-based products. This is particularly important for those at risk of getting insufficient amino acids, such as children, teenagers, lactating women, older people and those in developing countries.

Data has shown that gram for gram, animal proteins are more effective at supporting the maintenance of skeletal muscle mass as we age than plant proteins.

Metabolomics studies have also shown that, while food labels may make meat- and plant-based foods appear interchangeable, there are large differences in their nutritional profiles. Metabolites known to be important to human health were found either exclusively or in greater quantities in beef. However, plant-based alternatives contained several beneficial metabolites not found in beef, such as phenols and phytosterols. This indicates that one is not necessarily better than the other, but that, currently at least, they are not interchangeable.

**Milk** is another area where many people are looking to make a switch from animal- to plant-based alternatives. A comparison of **cow's milk** with unsweetened soy, rice, almond and coconut milk alternatives showed that, nutritionally, cow's milk still comes out on top as an all-round nutrient source as well as providing additional benefits. Of the plant-based alternatives, **soy milk**, which has been around for decades, provided the most balanced nutritional profile.

So, it would appear that, while great advances are being made in creating desirable and nutritious plant-based alternatives and uptake is improving even if environmental concerns may not be people's primary motivation, there is still work to be done.

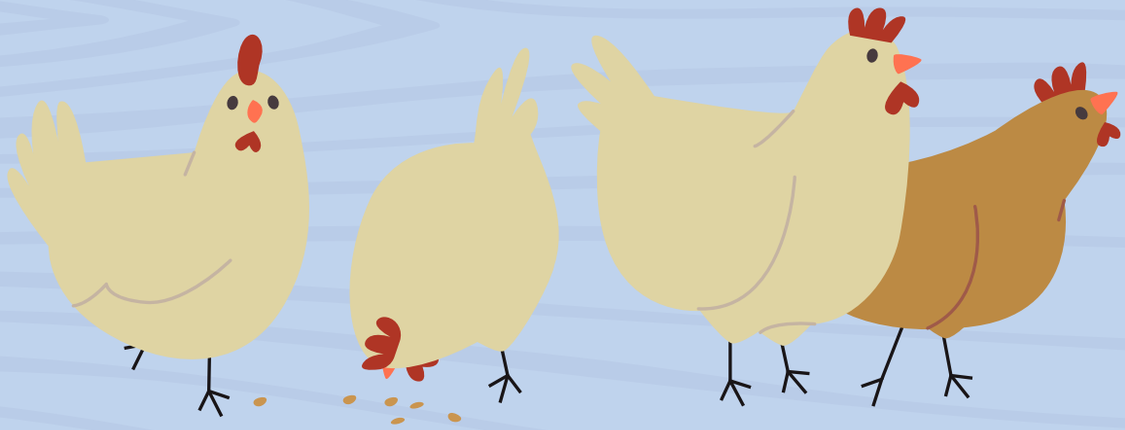
# INSECTS AS A PROTEIN SOURCE

For some cultures, insects have been an important protein source for centuries. To many in western cultures, however, the thought of eating insects isn't appealing. But there are many arguments towards including insects in our diets as a protein source or in livestock feed.

Insect meal and flours could be one way of incorporating insect proteins into our diets without the squeamish factor.

## INSECTS:

- Represent a rich protein source – they can yield many more times more edible protein per kg than beef
- Provide essential micronutrients
- Require less space for rearing than livestock
- Need less water than livestock (some species are drought-resistant too)
- Emit lower levels of greenhouse gases than livestock
- Have harvest cycles that are much shorter than for livestock

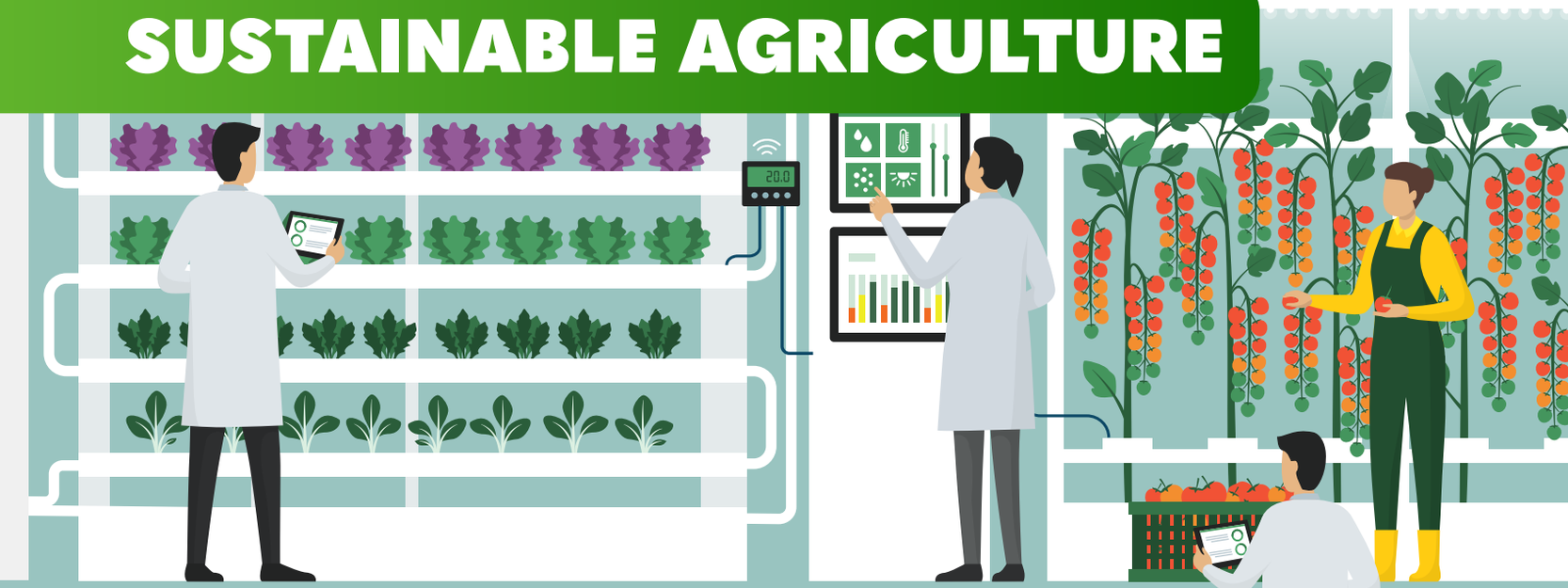


They are also being used to replace animal feed components such as fishmeal and soybeans in agriculture and aquaculture that have greater environmental and physical footprints. As a bonus, many species can also be raised on food scraps or animal manure, helping to reduce waste.

One group are taking this a step further and looking to combine the benefits of insects as a protein source and the scale, space and controllability of cellular agriculture by producing insect proteins via cellular agriculture.

There are still some remaining questions around **safety** from factors such as pesticides and toxins that may contaminate insects removed from the wild, allergies and the risk to humans and livestock posed by insect pathogens.

# SUSTAINABLE AGRICULTURE




Aside from producing animal products without animals and finding alternate protein sources, there are still many more ways in which food production can change to benefit the planet in the future. **VERTICAL FARMING** is being implemented in the production of some plant crops, helping to reduce land usage and enabling cultivation under fully controlled and automated conditions to optimize growth.

**COMBINED AQUAPONIC AGRICULTURAL SYSTEMS** are also proving fruitful. Here, the water containing waste products from farmed fish or crustaceans in aquaculture is used to water and nourish vegetable or rice crops. This increases the yield from the area and at the same time reduces water use and eutrophication.

**SEAWEEDS** have been highlighted as potential food sources of importance for the future, providing iodine, vitamins, minerals and protein. As well as converting carbon dioxide to oxygen, they aid carbon fixation, don't require a fresh water supply and are fast growing, providing a ready food source. Scientists are working on ways to make production efficient and scalable.

Scientists are also looking at ways that environmentally damaging food ingredients can be switched for more environmentally friendly ingredients. For example, switching out palm oil, which is associated with habitat loss, for microalgae-based oil.

# REDUCING WASTE

Finding ways to reduce the waste in our food system or to reuse or repurpose it will help to make it more sustainable. A number of solutions to tackle avoidable food waste have been proposed including:

- Changes in food packaging
- Changes in portion sizes
- Standardization of date-labeling terms:
  A lack of science behind "best by" and "use by" dates has been pointed to as a problem in generating unnecessary food wastage.
- Selling imperfect produce in retail stores
- Making food donations easier
- Feeding uneaten food to animals
- Implementing composting in communities
- Creating consumer education campaigns on food waste
- Taxing food waste

with "making food donations easier" and "standardizing date labels" the two options most favored by consumers and "taxing food waste" the least popular.

While there is increasing demand for "clean" foods that are free from preservatives, a lack of consumer understanding means that people are demanding the removal of harmless preservatives too that are necessary to prolong the food's shelf life. This in turn is leading to unnecessary food waste.

Packaging and coatings can play an important part in reducing food waste by:

- Keeping food fresher for longer with biologically-derived, bioactive and biodegradable solutions
- Reducing microbial contamination
- Reducing adherence of the contents to the packaging

**SENSORS** have also been developed that can detect ethylene, a sweet-smelling gas given off when flowers bloom and fruits and vegetables ripen. They can be used to monitor fruit and vegetables as they are shipped and stored, helping to reduce food waste.

Food production, processing and post-consumer waste products are finding second lives in food and non-food destinies, including turning:

- Fermented food waste into fertilizers and plant probiotics
- Restaurant scraps into biodiesel, electricity and bioplastic
- Grape pomace into grape seed oil, polyphenols, biofuel and biochar for wastewater treatment
- Agricultural waste into rechargeable batteries
- Fruit and vegetable scraps into robust construction materials
- Eggshells and tomato skins into tires
- Greek yogurt waste into biofuel
- Unsold bread into a fungus-based leather alternative
- Fermented soybean waste into a health supplement to help tackle high cholesterol and obesity
- Crustacean and fruit waste into chitin for use as a food thickener and stabilizer and in food packaging
- Dairy waste into a microbial food source to produce the food preservative nisin