

Next food revolution: Will synthetic proteins eliminate animals as food?

We are on the cusp of the deepest, fastest, most consequential disruption in food and agricultural production since the first domestication of plants and animals ten thousand years ago. This is primarily a protein disruption driven by economics. The cost of proteins will be five times cheaper by 2030 and 10 times cheaper by 2035 than existing animal proteins, before ultimately approaching the cost of sugar. They will also be superior in every key attribute – more nutritious, healthier, better tasting, and more convenient, with almost unimaginable variety. This means that, by 2030, modern food products will be higher quality and cost less than half as much to produce as the animal-derived products they replace.

The impact of this disruption on industrial animal farming will be profound. By 2030, the number of cows in the U.S. will have fallen by 50% and the cattle farming industry will be all but bankrupt. All other livestock industries will suffer a similar fate, while the knock-on effects for crop farmers and businesses throughout the value chain will be severe.

This is the result of rapid advances in precision biology that have allowed us to make huge strides in precision fermentation, a process that allows us to program microorganisms to produce almost any complex organic molecule.



The fermentation process. Credit: Dirt-to-Dinner

These advances are now being combined with an entirely new model of production we call Food-as-Software, in which individual molecules engineered by scientists are uploaded to databases – molecular cookbooks that food engineers anywhere in the world can use to design products in the same way that software developers design apps. This model ensures constant iteration so that products improve rapidly, with each version superior and cheaper than the last. It also ensures a production system that is completely decentralized and much more stable and resilient than industrial animal agriculture, with fermentation farms located in or close to towns and cities.

This rapid improvement is in stark contrast to the industrial livestock production model, which has all but reached its limits in terms of scale, reach, and efficiency. As the most inefficient and economically vulnerable part of this system, cow products will be the first to feel the full force of modern food's

disruptive power. Modern alternatives will be up to 100 times more land efficient, 10-25 times more feedstock efficient, 20 times more time efficient, and 10 times more water efficient.^{1,2} They will also produce an order of magnitude less waste.

Modern foods have already started disrupting the ground meat market, but once cost parity is reached, we believe in 2021-23, adoption will tip and accelerate exponentially. The disruption will play out in a number of ways and does not rely solely on the direct, one-for-one substitution of end products. In some markets, only a small percentage of the ingredients need to be replaced for an entire product to be disrupted. The whole of the cow milk industry, for example, will start to collapse once modern food technologies have replaced the proteins in a bottle of milk – just 3.3% of its content. The industry, which is already balancing on a knife edge, will thus be all but bankrupt by 2030.



This is not, therefore, one disruption but many in parallel, with each overlapping, reinforcing, and accelerating one another. Product after product that we extract from the cow will be replaced by superior, cheaper, modern alternatives, triggering a death spiral of increasing prices, decreasing demand, and reversing economies of scale for the industrial cattle farming industry, which will collapse long before we see modern technologies produce the perfect, cellular steak.

Summary of Findings:

By 2030, demand for cow products will have fallen by 70%. Before we reach this point, the U.S. cattle industry will be effectively bankrupt. By 2035, demand for cow products will have shrunk by 80% to 90%. Other livestock markets such as chicken, pig, and fish will follow a similar trajectory. There will be enormous destruction of value for those involved in rearing animals and processing them, and for all the industries that support and supply the sector (fertilizers, machinery, veterinary services, and more). We estimate this will total more than \$100bn. At the same time, there will be huge opportunities for the producers of modern foods and materials.

- Production volumes of the U.S. beef and dairy industries and their suppliers will decline by more than 50% by 2030, and by nearly 90% by 2035. In our central case, by 2030 the market by volume for ground beef will have shrunk by 70%, the steak market by 30%, and the dairy market by almost 90%. The market by volume for other cow products such as leather and collagen is likely to have declined by more than 90%. Crop farming volumes, such as soy, corn, and alfalfa, will fall by more than 50%.
- The current industrialized, animal-agriculture system will be replaced with a Food-as-Software model, where foods are engineered by scientists at a molecular level and uploaded to databases that can be accessed by food designers anywhere in the world. This will result in a far more distributed, localized food-production system that is more stable and resilient than the one it replaces. The new production system will be shielded from volume and price volatility due to the vagaries of seasonality, weather, drought, disease and other natural, economic, and political factors. Geography will no longer offer any competitive advantage. We will move from a centralized system dependent on scarce resources to a distributed system based on abundant resources.
- By 2035, about 60% of the land currently being used for livestock and feed production will be freed for other uses. This represents one-quarter of the continental U.S. – almost as much land as was acquired during the Louisiana Purchase of 1803. The opportunity to reimagine the American landscape by repurposing this land is wholly unprecedented.
- Modern foods will be cheaper and superior to animal-derived foods. The cost of modern food products will be half that of animal products and they will be superior in every functional attribute – more nutritious, tastier, and more convenient with much greater variety. Nutritional benefits could have a profound impact on health, both in a reduction in foodborne illness and in conditions such as heart disease, obesity, cancer, and diabetes that are estimated to cost the U.S. \$1.7 trillion every year.
- Wider economic benefits will accrue from the reduction in the cost of food in the form of increased disposable incomes and from the wealth, jobs, and taxes that come from leading the way in modern

food technologies.

- Environmental benefits will be profound, with net greenhouse gas emissions from the sector falling by 45% by 2030. Other issues such as international deforestation, species extinction, water scarcity, and aquatic pollution from animal waste, hormones, and antibiotics will be ameliorated as well. By 2035, lands previously used to produce animal foods in the U.S. could become a major carbon sink.



Credit: Shutterstock

Key Impacts of the Food and Agriculture Disruption

Economic

- The cost of modern foods and other precision fermentation products will be at least 50% and as much as 80% lower than the animal products they replace, which will translate into substantially lower prices and increased disposable incomes.
- At current prices, revenues of the U.S. beef and dairy industry and their suppliers, which together exceed \$400bn today, will decline by at least 50% by 2030, and by nearly 90% by 2035. All other livestock and commercial fisheries will follow a similar trajectory.
- The volume of crops needed to feed cattle in the U.S. will fall by 50%, from 155 million tons in 2018

to 80 million tons in 2030. This means that, at current prices, feed production revenues for cattle will fall by more than 50%, from \$60bn in 2018 to less than \$30bn in 2030.

- Farmland values will collapse by 40%-80%. The outcome for individual regions and farms depends on the land's alternative uses, amenity value, and policy choices that are made.
- Major producers of animal products are at risk of a serious economic shock. Countries that produce large quantities of conventional animal products and inputs to animal farming like Brazil, where more than 21% of GDP comes from agriculture – 7% of which is from livestock alone – are particularly vulnerable.
- The average U.S. family will save more than \$1,200 a year in food costs. This will keep an additional \$100bn a year in Americans' pockets by 2030.

money stack

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- By 2030, at least half of the demand for oil from the U.S. agriculture industry – currently running at about 150 million barrels of oil equivalent a year – will disappear as all parts of the supply chain related to growing and transporting cattle are disrupted. Savings on transportation costs will result in a permanent boost in annual disposable income for U.S. households, totaling \$1 trillion by 2030. Consumer spending is by far the largest driver of the economy, comprising about 71% of total GDP and driving business and job growth throughout the economy.

Environmental

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By 2035, 60% of the land currently used for livestock and feed production will be freed for other uses. This 485 million acres equates to 13 times the size of Iowa, an area almost the size of the Louisiana Purchase.

- If all this freed land were dedicated to reforestation and efforts were made to utilize tree species and planting techniques intended to maximize carbon sequestration, all current sources of U.S. greenhouse gas emissions could be fully offset by 2035.
- U.S. greenhouse gas emissions from cattle will drop by 60% by 2030, on course to nearly 80% by 2035. Even when the modern food production that replaces animal agriculture is included, net emissions from the sector as a whole will decline by 45% by 2030, on course to 65% by 2035.
- Water consumption in cattle production and associated feed cropland irrigation will fall by 50% by 2030, on course to 75% by 2035. Even when the modern food production that replaces animal agriculture is included, net water consumption in the sector as a whole will decline by 35% by 2030, on course to 60% by 2035.



Social

- Higher quality, more nutritious food will become cheaper and more accessible for everyone. In the developing world in particular, access to cheap protein will have a hugely positive impact on hunger, nutrition, and general health.
- Half of the 1.2 million jobs in U.S. beef and dairy production and their associated industries will be lost by 2030, climbing towards 90% by 2035.
- The emerging U.S. precision fermentation industry will create at least 700,000 jobs by 2030 and up to one million jobs by 2035.

Geopolitical

- Trade relations will shift because decentralized food production will be far less constrained by geographic and climatic conditions than traditional livestock farming and agriculture.
- Major exporters of animal products, like the U.S., Brazil, and the European Union, will lose geopolitical leverage over countries that are currently dependent upon imports of these products. Countries importing animal products can more easily produce these products domestically at a lower cost using modern production methods.
- Large endowments of arable land and other natural resources are not required to lead the disruption, so the opportunity exists for any country to capture value associated with a global industry worth trillions of dollars that ultimately emerges over the course of this disruption.

Choices

The disruption of food and agriculture is inevitable – modern products will be cheaper and superior in every conceivable way – but policymakers, investors, businesses, and civil society as a whole have the power to slow down or speed up their adoption. The aim of this report is to start a conversation and focus decisionmakers' attention on the scale, speed, and impact of the modern food disruption. The choices they make in the near term will have a lasting impact – those regarding IP rights and approval processes for modern food products, for example, will be critical.

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Many decisions will be driven by economic advantages as well as by social and environmental considerations. But other decisions may be influenced by incumbent industries seeking to delay or derail the disruption. They may also be influenced by mainstream analysis, although decisions made based on such analysis tend to make economies and societies poorer by locking them into assets, technologies, and skill sets that are uncompetitive, expensive, and obsolete. To unlock the full potential of this and every other technological disruption, we need to embrace a different approach, one that better reflects the complex, dynamic, and rapidly-changing world we live in.

Decision-makers must also recognize there are no geographical barriers to the food and agriculture disruption, so if the U.S. resists or fails to support the modern food industry, other countries such as China will capture the health, wealth, and jobs that accrue to those leading the way. Policymakers must, therefore, start planning for the modern food disruption now in order to capture the extraordinary economic, social, and environmental benefits it has to offer.

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