Food for Thought

The Protein Transformation

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As a pure play global pioneer with privileged access in the Food 4.0 ecosystem, Blue Horizon has shaped the growth of the alternative proteins market. The company aims to transform the global food industry through impact capital and value creation, and invests across the lifecycles of companies that are mission aligned to replace animal proteins with healthy and sustainable alternative sources of protein. Blue Horizon was founded by Roger Lienhard in 2016 and is based in Zurich. To date, the company has raised over USD 650 million and invested in more than 50 companies in the alternative protein sector. Its business model offers an attractive opportunity to invest in the evolution of the global food ecosystem while contributing to a healthy and sustainable world. www.bluehorizon.com.

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Alternative Proteins in Context

In just the past few years, alternative proteins have morphed from a niche product to a mainstream phenomenon. Plant-based meats are now a fixture at fast-food restaurants around the world, plant-based milk is a household staple, and you can taste meat grown from animal cells in restaurants in Singapore and Israel.

What we see today is only the beginning of the protein transformation.

Based on our analysis, by 2035, every tenth portion of meat, eggs, and dairy eaten around the globe is very likely to be alternative. That's a lot. If the alternative-protein market were a country, by then it would be a top-50 economy, larger than Finland's 2020 GDP. Is this unrealistic? Not at all. And it could be much more, if all four of the dominoes now lined up were to tip over.

The first domino is already falling: public concern for the climate—and, more broadly, sustainability—is rife. Many consumers want to reduce the amount of animal protein in their diets, especially if they can do it without sacrificing taste or paying more. In addition, fully 85% of investors now incorporate environmental, social, and corporate governance (ESG) criteria into their investment strategies.

We predict that, taken together, these concerns will generate enough consumer demand and investor interest to tip over the second domino: refinement and scaling of existing technologies to unlock parity, when the taste, texture, and price of alternative proteins closely match those of animal proteins. The first two dominoes are all that's needed to allow alternative proteins to capture 11% of the global protein market by 2035, our base-case growth estimate.

What if the industry can generate even more momentum? Step changes in alternative-protein technology, whether at incumbent food companies or startups and supported by public or private investment, could lead to rapid gains in production efficiency, better taste and texture, and lower cost. The result: the third domino falls, leading to earlier parity and a 16% market share by 2035.

The final domino could fall if regulators give it a push. Higher carbon prices and support for farmers transitioning from animal agriculture to alternative-protein inputs could boost consumption to 22% by 2035. At that rate, Europe and North America would reach "peak meat" by 2025, and then the consumption of animal protein in those markets would actually begin to decline.

The rise of alternative proteins is a transformation, not a revolution. Several major incumbent meat companies are already redefining themselves as "protein" companies, making and marketing their own alternatives. This makes sense, given the size of the prize. We estimate that alternative-protein revenues will reach $290 billion in 2035, with the profits distributed throughout the value chain: to the startups and incumbent food companies producing alternatives, the upstream players providing the industry with the inputs and tools needed to unlock these revenues, and the investors willing to support their efforts.

Profits aside, the protein transformation can make an enormous contribution to the efforts to combat climate change. In our base case, by 2035, the shift to plant-based meat and eggs alone will have saved more than 1 gigaton of CO_2-e.[1] That's the equivalent of Japan going completely carbon neutral for an entire year.[2] Eating that much plant-based protein would save enough water to supply the city of London for 40 years[3] and make a major contribution to food security and our planet's biodiversity.

Alternative proteins also open up an opportunity for individuals to contribute to the fight against climate change. For instance, every portion of spaghetti Bolognese made with plant-based meat avoids as much greenhouse gas as a new car emits when driven 10 kilometers.

Nine out of ten of the world's favorite dishes will have a realistic alternative by 2035.

So what does the protein transformation taste and feel like, and how much will it cost the consumer? Good news: it will require few material sacrifices. As alternative proteins reach parity with animal proteins in taste, texture, and price, they can replace animal protein in 90% of the world's ten favorite dishes, from burritos to dim sum. These alternatives won't require new recipes, change the taste of what people love to eat, or cost a lot. Making that Bolognese sauce with alternative meat will be just as easy and taste just as good. It also won't burn a hole in consumers' wallets.

In this first-of-its-kind report, we crystallize the expertise of the alternative-protein field, on the basis of a recently conducted survey and more than 40 interviews with industry veterans, researchers, and startup entrepreneurs. We provide detailed forecasts of the growth potential of the market for alternative plant-, microorganism-, and animal-cell-based proteins that can directly replace conventional animal protein, excluding traditionally plant-based foods such as pulses, tofu, and tempeh. We support our model with deep dives into the relevant protein production technology. From this body of knowledge, we then identify the most exciting investment themes along the value chain.

We also aim to answer key questions posed by all stakeholders, including farmers, incumbent food companies, startups, investors, and consumers: How will parity determine the future growth of the market? What will be required to bring each type of alternative protein to parity, and when will that happen? How can investors both support and benefit from its growth?

The Promise of Parity

Alternative proteins could soon match animal protein in taste, texture, and price, fueling widespread adoption.

Consumers' appetite for alternative proteins is growing, as animal-free protein emerges as a healthy choice. A recent Stanford study, for example, showed that eating plant-based alternatives instead of conventional animal proteins reduces cardiovascular-disease risk factors.[4] The health of the planet stands to benefit, too, thanks to the potential of these proteins to decrease greenhouse gas emissions as well as water and land use. (See the sidebar "Making Protein Sustainable.")

Issues surrounding animal suffering and biodiversity loss are also playing an important role in the shift away from animal protein. Concerns about the ethics of intensive animal farming have already increased demand for grass-fed meat and free-range chicken and eggs. In addition, the risk of animal-borne illnesses such as mad-cow disease has come into sharp focus in light of the COVID-19 pandemic.

The market for alternative proteins is still nascent—13 million metric tons were consumed globally in 2020, just 2% of the animal protein market. Large numbers of consumers, however, say they are willing to try to change that. A recent study found that about 11% of consumers in the US, UK, and Germany are very interested in alternative proteins; 66% are somewhat interested, indifferent, or somewhat not interested; and only 23% are not interested at all. For consumers who aren't very interested, the key changes that would increase their interest are improved taste and a lower price.[5]

In short, alternative proteins must reach parity with animal proteins in three key areas:

- **Taste.** Alternative proteins must effectively imitate the well-known flavor—and smell—of meat, seafood, dairy, and eggs.

- **Texture.** Alternatives must also look and feel the same as animal proteins. The experience of eating meat depends largely on its fibrous structure. Fish appears flaky, cheese feels hard or stretchy. Alternative eggs and dairy must also behave like real eggs and dairy when being cooked; eggs alone have up to 70 different uses, from scrambled to merengue to mayonnaise to cakes, and alternatives must be able to be used in all these cases.

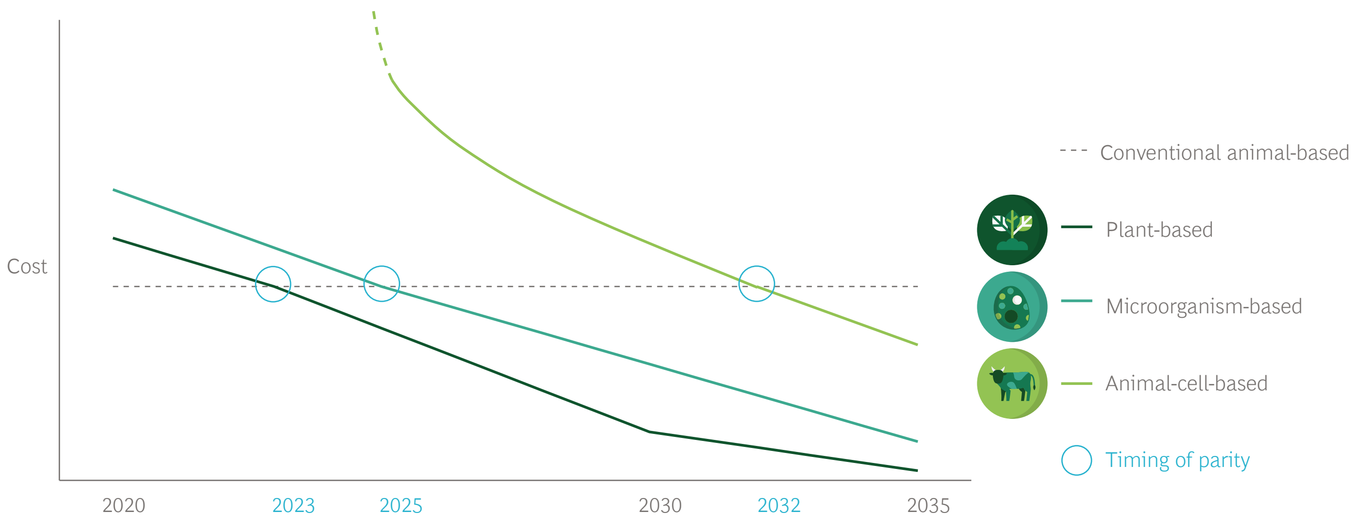
- **Price.** At present, alternative proteins are usually not the bargain option, compared with animal proteins. If large groups of consumers are to repeatedly purchase alternative proteins, the cost must match or undercut that of protein from animals farmed under nonorganic conditions.

Nick Halla, the senior vice president for international at Impossible Foods, summarizes the issue of parity as follows: "You'll buy the product once based on novelty, you'll come back if the taste was good and if there are benefits such as nutrition and sustainability, and you'll buy it in the long run if the value is right."

Each of the three types of alternative protein is currently at a different stage of parity with conventional proteins. We expect that plant-based alternative proteins will achieve parity by 2023, those based on microorganisms by 2025, and those based on animal cells by 2032. (See Exhibit 1.)

Exhibit 1 - Alternative Proteins Can Reach Parity Between the Early 2020s and the Early 2030s

Relative timing of cost parity for alternative proteins with realistic taste and texture[1]



Sources: Expert interviews; industry reports; Blue Horizon and BCG analysis.

[1]Illustrative data for US and EU; variations by product group and geographic area are omitted for clarity.

Making Protein Sustainable

The adoption of alternative proteins will have a measurable positive impact on the environment. Emissions from conventional animal farming stem mostly from the production of methane and nitrous oxide during animal digestion, from manure, and from the use of chemical fertilizers, fuel, and electricity. By 2035, the shift to plant-based beef, pork, chicken, and egg alternatives will save more than 1 gigaton of CO_2-e, about as much as Japan currently emits annually.[1] Compared with conventional animal-based proteins, production of plant-based alternatives emits one-eighth the CO_2-e per kilogram for chicken, one-third for eggs, one-twelfth for beef, and one-ninth for pork.

By 2035, the transition away from animal agriculture will also save 39 billion cubic meters of water, enough to supply the city of London for 40 years. Likewise, more than 240,000 square kilometers of farmland will not be needed to grow animals and their feed, equal to the area of the UK. This space will be freed up over the next 15 years, increasing biodiversity as land formerly used for intensive agriculture reverts to a more natural state.

Further benefits are expected from the adoption of alternatives to seafood and dairy and from shifts to microorganism- and animal-cell-based alternatives. Overall, the transition to alternative proteins could contribute to at least six of the UN's Sustainable Development Goals: zero hunger, good health and well-being, responsible consumption and production, climate action, life below water, and life on land. To secure these societal benefits, however, holistic stakeholder management is required—especially by protecting the livelihoods of farmers through the reallocation of government subsidies, for example.

1. Based on consumption data from our base-case market model, assuming emissions per kilogram of conventional and alternative protein, as outlined in the Blue Horizon study *Environmental Impacts of Animal and Plant-Based Food*.

These dates will vary to some degree, depending on the type of animal protein being replaced. Plant-based burgers, for example, are very close to parity today and may reach it within the next two years. Plant-based chicken pieces, however, will likely only reach full parity after 2023. They are already close in taste and texture but need to get less expensive in order to compete with conventional mass-produced chicken. Microorganism- and animal-cell-based products will first reach parity with more expensive animal products such as meat; achieving parity with eggs and dairy will take more time.

A Fast-Growing Market

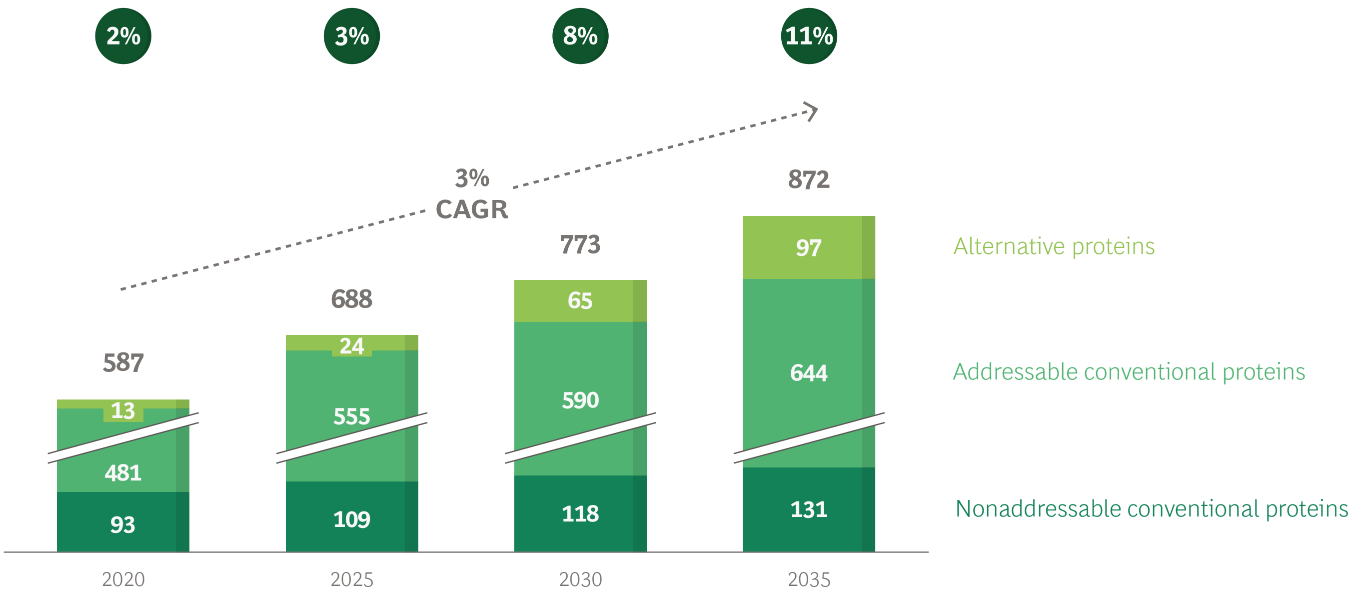
By 2035, every tenth portion of protein is very likely to be alternative.

How large will the alternative-protein market grow, and how quickly will it get there? In our base-case scenario, we expect the alternative-protein market will increase to more than seven times its current size over the next decade and a half, from 13 million metric tons a year now to 97 million metric tons by 2035, when it will make up 11% of the overall protein market. (See Exhibit 2.) Assuming average revenues of $3 per kilogram, this amounts to a market of approximately $290 billion. Real revenues are likely closer to $10 per kilogram for high-quality meat alternatives but significantly less for high-volume products like milk.

We predict that adoption of alternative proteins—the proportion of total protein consumption made up of alternatives—will grow in three phases. Until each product type reaches parity, uptake will continue to increase at the current rates. Once the products reach parity, interest in them will soar, and the rate of adoption will double. This level of high interest will then remain steady for five years, after which use will continue to expand at a base rate of about 5%.

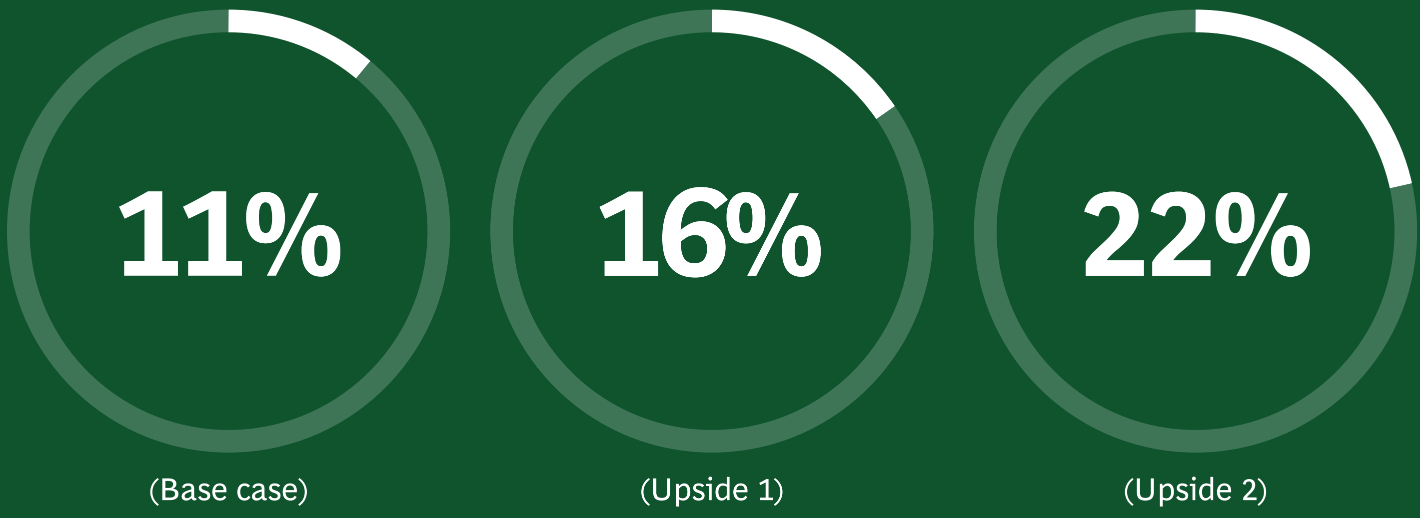
Exhibit 2 - Alternative Proteins Will Very Likely Account for 11% of the Protein Market in 2035

Global consumption of protein products
(% adoption rate, million metric tons, base-case scenario)



Sources: US Department of Agriculture; Euromonitor; UBS; ING; Good Food Institute; expert interviews; Blue Horizon and BCG analysis.

Note: Addressable proteins include ground meat, fillet, milk, eggs, and other forms of animal protein for which like-for-like alternatives can be created by building on current technology. Nonaddressable proteins include highly structured meat such as large cuts with bones.



Alternative-protein share of the overall protein market in 2035

Market Share Depends on Parity with Conventional Proteins

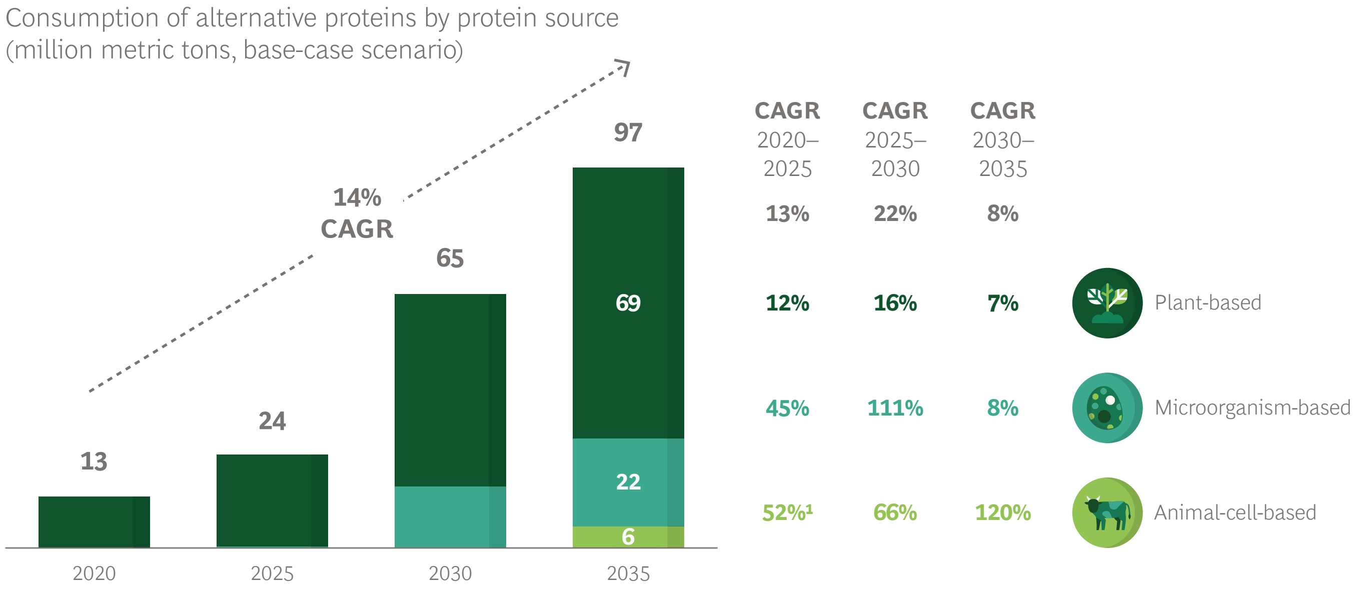
"You'll buy the product once based on novelty, you'll come back if the taste was good and if there are benefits such as nutrition and sustainability, and you'll buy it in the long run if the value is right."

—Nick Halla, Impossible Foods

Exhibit 3 shows the results of these waves of growth. Once plant-based alternatives reach parity, in 2023, a five-year period of soaring interest and steeply increasing adoption will ensue. Proteins based on microorganisms will likely reach parity by 2025 and then grow the fastest until 2032, when animal-cell-based protein will reach parity. After that, this protein's growth rate will top that of the other two, although total consumption of animal-cell-based protein will remain relatively small compared with the others until companies can scale up production.

Milk and other dairy alternatives, already the most widely used alternative-protein products, will likely remain the largest portion of the market through 2035. Egg substitutes will grow more quickly, however; the first realistic alternatives are available today. The market for alternatives to meat, especially chicken, and seafood will increase especially fast, rising from 21% of total alternative-protein consumption in 2020 to almost 37% in 2035. We anticipate that alternative cheese will remain a relatively small market, as producing realistic substitutes has proved to be especially challenging. (See Exhibit 4.)

Exhibit 3 - Alternative Protein Consumption Will Grow in Three Waves

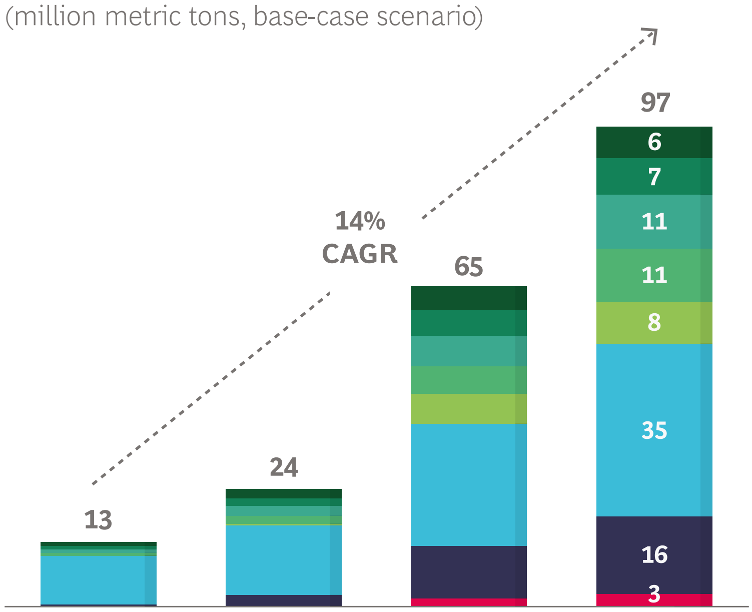


Sources: US Department of Agriculture; Euromonitor; UBS; ING; Good Food Institute; expert interviews; Blue Horizon and BCG analysis.

[1]CAGR from 2022 to 2025, starting from market entry.

Exhibit 4 - Milk and Other Dairy Alternatives Will Dominate the Market, Followed by Chicken and Seafood

Consumption of alternative proteins by product (million metric tons, base-case scenario)



CAGR 2020–2025	CAGR 2025–2030	CAGR 2030–2035	
13%	22%	8%	Total
19%	21%	6%	Beef[1]
22%	27%	8%	Pork
20%	26%	12%	Chicken
22%	28%	14%	Seafood
68%	79%	7%	Eggs
7%	12%	7%	Milk
36%	36%	8%	Fresh dairy
40%	50%	8%	Cheese

Sources: US Department of Agriculture; Euromonitor; UBS; ING; Good Food Institute; expert interviews; Blue Horizon and BCG analysis.

[1]Including veal.

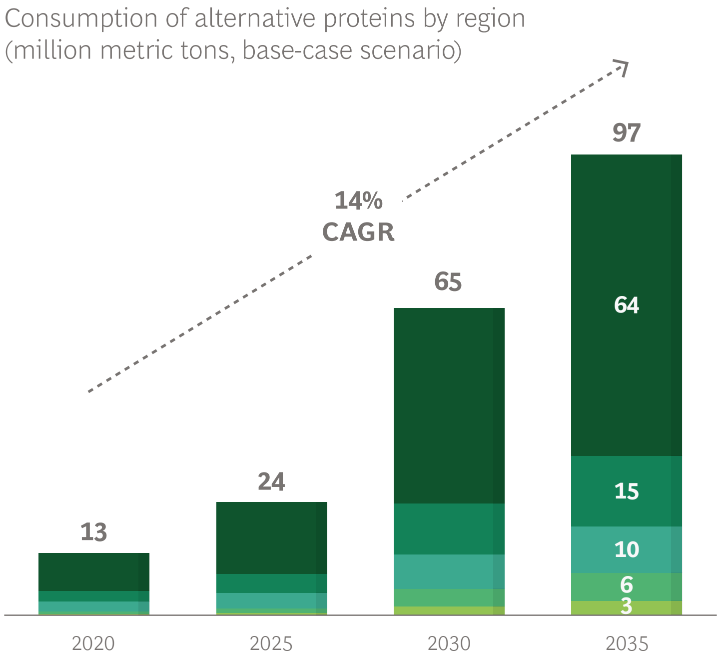
Note that none of our estimates of market size takes into account the possibility of using alternative proteins as a basis for animal feed. Replacing the fishmeal and bone meal used as feed in aquaculture and other types of animal farming could grow into a sizable market even more quickly than alternatives for human consumption.

On a regional basis, North America (defined as the US and Canada) and Europe are the most mature markets for alternative proteins, with a number of such products on grocery shelves for several years. Adoption in both markets is likely to grow quickly, thanks in part to their climate- and health-conscious populations.

The largest opportunity lies in Asia-Pacific, however. (See Exhibit 5.) Growth in that region is being driven by a large and growing population that is consuming more proteins as it becomes wealthier; the market will account for two-thirds of global consumption by 2035.

Latin America and the rest of the world will grow rapidly but remain considerably smaller.

Exhibit 5 - Asia-Pacific, the Largest Market for Alternative Proteins, Will Continue to Grow the Fastest



CAGR 2020–2025	CAGR 2025–2030	CAGR 2030–2035	
13%	**22%**	**8%**	Total
14%	**22%**	**9%**	Asia-Pacific
12%	**22%**	**7%**	Europe
9%	**17%**	**6%**	North America[1]
12%	**31%**	**10%**	Latin America
12%	**32%**	**10%**	Rest of the world

Sources: US Department of Agriculture; Euromonitor; UBS; ING; Good Food Institute; expert interviews; Blue Horizon and BCG analysis.

[1]North America includes only the US and Canada.

What’s for Dinner?

Parity will enable consumers to make 90% of the world’s favorite dishes with alternative proteins.

What will the protein transformation taste and feel like for consumers? Regional diets and tastes among the world's consumers vary considerably, as do the appropriate protein substitutes for many regionally popular foods. As Exhibit 6 indicates, many popular dishes around the world could be made with alternative proteins by 2025, especially those using less-structured meat, such as ground beef. Perhaps unsurprisingly, many of these dishes—pasties, dumplings, and heavily seasoned sauces, for instance—were originally designed to disguise the use of less appetizing parts of animals.

We expect that viable alternatives will eventually be found for all egg and dairy products, as well as most structured meat and fish such as fillets. Once that happens, 90% of the world's favorite dishes could be made using alternatives, with no sacrifices in taste or cost.

Highly structured, large cuts of meat, such as brisket with strong fat marbling or steak with bones, are the least likely to be replaced at parity by 2035. It's a lot harder to make alternative T-bone steaks than hamburgers—but 40% of the beef we consume is ground beef.

For consumers, parity will make the choice to use alternative proteins much easier, as it will allow people to prepare the dishes they love, without having to pay more or accept any change in taste.

Exhibit 6 - Many Popular Global Dishes Will Have a Tasty, Economical Alternative by 2035

Favorite conventional protein-based dishes per region and availability of alternatives

North America	Europe	Asia-Pacific	Latin America
Lasagna	Pizza	Sushi	Ceviche (fish salad)
Nachos with cheese/meat	Sandwiches	Ramen (noodle soup with egg or meat pieces)	Churrasco (grilled meat)
Macaroni and cheese	Pasta (e.g., Bolognese)	Dim sum (dumplings)	Alfajor (cookies with condensed milk and eggs)
Spaghetti with meatballs	Pies and pasties	Yakiniku (meat pieces, grilled)	Asado (grilled meat)
Quesadilla (tortilla with cheese and meat)	Duck breast	Jiaozi (dumplings)	Milanesa (breaded meat)
Burritos	Steak with fries	Yakitori (skewered chicken pieces)	Feijoada (pork and bean stew)
Pasta Alfredo (butter, cheese)	Roast	Baozi (filled buns)	Arepas (cornbread with butter)
Pasta, chicken, and garlic	Beef bourguignon (stew)	Onigiri (filled rice balls)	Moqueca (seafood stew)
Honey-baked ham	Salad (e.g., caesar salad)	Kimchi (pickles with shrimp paste)	Lomo saltado (beef slices)
BBQ brisket	Tartiflette (potato gratin)	Biryani (rice with meat pieces)	Coxinha (croquette with chicken filling)

Taste, texture, and price parity by 2025 (e.g., ground meat, fillet, dairy)

Taste, texture, and price parity by 2035 (e.g., structured meat, cheese)

Not or only partially substitutable by 2035 (e.g., highly structured meat)

Sources: YouGov; Statista; TasteAtlas; Blue Horizon and BCG analysis.

Building the Protein Value Chain

Parity can be reached by developing and scaling up existing technologies at key steps of the value chain.

The growth of the alternative-protein market depends largely on consumers' willingness to use these substitutes in their chosen diets. Acceptance depends on parity, and parity depends on boosting the technological expertise and manufacturing efficiency to produce these alternatives at scale. How will parity be achieved? In the following sections, we describe the current state of the art and analyze what will be needed to achieve full parity.

Each of the three types of alternative proteins must pass through similar steps in the production process, from sourcing and growing the required plants, microorganisms, and animal cells and extracting their protein to formulating the right taste and creating the proper texture. (See Exhibit 7.) The analysis below shows which improvements in each step will contribute to the effort to reach parity and unlock the alternative-protein market's growth. To confirm our analysis, we also conducted a survey of industry players to determine where, in their view, the most promising value creation opportunities lie.

Exhibit 7 - Taste, Texture, and Price Parity Depends on Improvements in Key Steps in the Value Chain

	Production and sourcing			Processing		
	Source	Growth	Harvest	Extraction	Formulation	Texturizing
Plant-based	1 Optimization of protein crops		—	2 Improvement of protein extraction	3 Reduction in the cost and complexity of additives	4 Scaling of texturizing capacity
Microorganism-based	1 Increase in metabolic efficiency	2 Adoption of low-cost feedstocks	3 Optimization of harvesting and protein extraction processes[1]		4 Reduction in the cost and complexity of additives	—[2]
Animal-cell-based	1 Increase in metabolic efficiency	2 Decrease in media cost and dynamic media adjustment	—	—	3 Adoption of key non-muscle-meat ingredients	

Sources: Blue Horizon and BCG analysis.

Note: The list of measures is not exhaustive, focusing only on the measures with the greatest impact.

¹Applicable only to precision fermentation.

²Additional texturizing may be needed when using precision fermentation; the challenges are similar to texturizing plant-based proteins.

Plant-Based Alternatives

> Plant-based alternatives need optimized protein crops, improved protein extraction, clean formulations, and large-scale texturizing.

Plant-based alternative proteins, typically derived from soybeans and yellow peas, are already approaching parity with conventional protein. Products like Beyond Meat's various meat alternatives and Impossible Foods' ground beef closely resemble conventional proteins in taste and texture. Beyond Meat's plant-based products are already sold in grocery stores, restaurants, and fast-food outlets such as McDonald's and Pizza Hut; when the company went public in May 2019, its shares soared 163% on its first day of trading. Other segments are close behind; the Just Egg scrambled-egg substitute and multiple soy- or pea-based chicken alternatives are proving very popular.

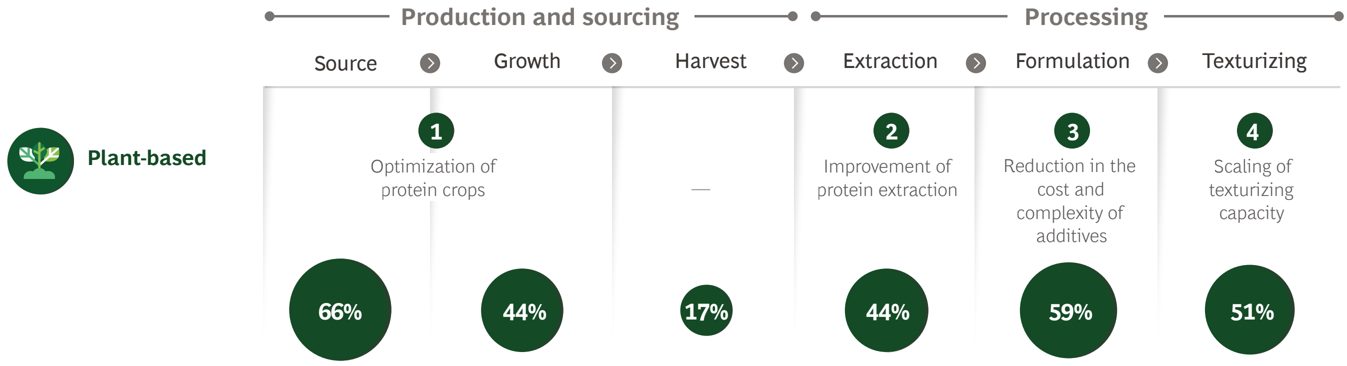
Today, the cost of goods sold for realistic plant-based alternative proteins is still about two times the cost of conventional animal proteins. To improve this ratio, the industry must optimize and scale up every step of the way. Improving sourcing and growth are prerequisites for production at scale, while perfecting extraction, formulation, and texturizing will significantly reduce costs. The results of our survey confirm this: the majority of respondents pointed to sourcing, formulation, and texturizing as the biggest challenges, with the greatest value creation opportunities (see Exhibit 8):

1. **Optimizing Protein Crops.** Neither soy nor pea has been optimized for use in alternative-protein products. Most of the soy grown today has been bred for animal feed. New varieties, more suitable for human consumption, must be developed and grown with fewer off-colors and off-flavors so that fewer additives are needed to make tasty products. The protein content of soy and peas must also be increased to reduce the amount of input crops needed per kilogram of finished product and lower the cost of extracting the protein.

2. **Improving Protein Extraction.** The process of extracting the protein from crops is growing in technical sophistication and scale but still has to be improved and scaled up. Today, if the pH of the water used in extraction isn't properly balanced, the entire process can be disrupted. Improving the extraction process can lower the cost and increase the quality of the final product by removing more of the off-flavors, reducing the need for expensive and unappealing chemical additives.

   We expect optimized extraction to decrease production costs, driven by savings in the capital-intensive separation and drying steps. Additionally, while the cost of soybean extraction can be offset by the production and sale of byproducts such as soybean cooking oil, viable uses for the byproducts of pea extraction have yet to be found.

Exhibit 8 - Experts See the Greatest Potential for Value Creation in Improved Crops, Formulation, and Texturizing



Question: For which value chain steps in the alternative-protein space do you see high potential for differentiation and value creation (e.g., significant technological development, improvements in product characteristics)?

Multiple answers were possible. Bubble size shows the proportion of respondents selecting each value chain step (N = 41 experts answered this question).

Sources: Industry survey of 59 experts, conducted by Blue Horizon and BCG, November–December 2020; Blue Horizon and BCG analysis.

Note: The list of measures is not exhaustive, focusing only on the measures with the greatest impact.

3. **Reducing the Cost and Complexity of Additives.** Making tasty alternative proteins from plants is largely a matter of choosing the right ingredients to mix with the extracted protein. To reach parity, new taste and texturizing ingredients will be needed. Consumers want foods that are completely free of animal products, and thus substitutes for commonly used binding agents like gelatin and egg whites need to be found. Foods must also be "natural," however, so ingredients such as methylcellulose, a chemical used as a binding agent in many industries, are becoming less popular. In addition, ingredients must be familiar; many companies are looking to replace artificial flavors with suitable plant extracts.

Atze Jan van der Goot, a professor at Wageningen University, notes, "If you find something that works the same way methylcellulose does, is cheap, and has a name that people can pronounce, it could become the industry standard very quickly."

4. **Scaling of Texturizing Capacity.** The final step in the process of producing plant-based alternative proteins is to create the proper texture. This is accomplished primarily by extruding the formulated product through an opening in a perforated plate or die designed to give the required texture and shape. High-moisture extrusion can create structured products like chicken pieces, while low-moisture extrusion can produce smaller granules that, once rehydrated, can be made into burgers and other products.

   Properly texturizing alternative proteins remains a significant economic bottleneck for the industry. Experimentation is expensive: highly skilled extruder operators must be able to experiment with large batches of product and adjust many parameters in order to perfect the final texture. In addition, the machinery is highly capital intensive. Production of the final product therefore must increase from the current hundreds of kilograms per hour to thousands in order to bring unit costs down to a reasonable level.

   New technologies may soon complement extrusion. For instance, a team led by Professor van der Goot has developed shear cells, which shred (or shear) protein mixtures at high temperature to create fibrous structures; they can generate very realistic fibers and are well suited for small- to medium-scale manufacturing of specialized products. This offers the potential for radical decentralization—gourmet restaurants might even be able to make bespoke alternative-protein dishes right in the kitchen.

Unlike plant-based meat, plant-based dairy, egg, and cheese products do not need to be texturized. Achieving parity for these products will thus depend on the adoption of optimized protein crops and improvements in extraction and formulation. (See the sidebar "State-of-the-Art Eggs.") For cheese, the Swiss company New Roots has identified cashew nuts as an efficient input, requiring just one kilogram of input for every two kilograms of finished cheese; the remainder is mostly added water. In contrast, it takes 10 to 15 liters of milk to make one kilogram of animal cheese.

State-of-the-Art Eggs

The world eats a lot of eggs—about 1.2 trillion of them in 2020, or more than 150 eggs per person worldwide.[1] Eggs are notoriously hard to replace because they are used in so many different ways, but several companies are finding real success with egg substitutes.

The leading product in the market today is Eat Just's plant-based Just Egg. Made from mung beans, it can be scrambled and used in omelets and other recipes that require mixed egg yolk and white, replacing 72% of the common uses of eggs, according to the company. Just Egg is not yet available in Europe, but the company has established partnerships with protein processor Emsland Group and manufacturer PHW Group to expand there.

Clara Foods produces recombinant egg white proteins in genetically modified yeast. The production of egg whites, rather than a mixture of whites and yolks, suggests that the future may be in "deconstructing" eggs, making different combinations of taste and texture for different uses.

Today, just 25,000 tons of egg substitutes are consumed annually around the world. We expect that number to rise rapidly, however, to 8 million tons by 2035—about 10% of all the eggs we eat.

1. The data sources are as follows: the 60 million tons is based on our market model; the weight of a midsize egg is 49.6 grams according to the US Department of Agriculture; the world population is 7.8 billion per Yale University.

Microorganism-Based Alternatives

> Microorganism-based alternatives need more efficient growth on less costly feedstocks, optimized extraction, and clean formulations.

In second place in the race to reach parity are microorganism-based alternatives. These include proteins produced using bacteria, yeasts, single-celled algae, or fungi that are flavored and texturized into edible products. The process begins with a specific strain of microorganism that is then grown in a carbohydrate-rich solution to produce protein through fermentation.

Two technologies are currently being used to make microorganism-based alternative proteins. In the first, filamentous fungi are grown in a solid-state culture, a technique used primarily to produce meat alternatives, and all of the resulting biomass is included in the final product. In the second, microorganisms such as fungi, bacteria, or algae are grown in liquid suspension culture, from which a specific protein is extracted, rather than the complete biomass. This process is called precision fermentation because it targets a single protein.

Microorganism-based alternatives are not new. The UK's Marlow Foods, founded in 1985, was the first company to develop a process for creating microorganism-based alternatives for human consumption and has been selling its meat replacement product, called Quorn, since 1993. More recently, several companies, including US-based Meati Foods, have been experimenting with filamentous fungi that can generate realistic meat-like fibrous structures. Microorganisms also hold the promise of making realistic substitutes for eggs and cheese by enabling the production of proteins directly responsible for specific physical properties; Clara Foods, for example, produces foamy egg white protein substitutes that can be used in applications like merengue.

Microorganisms can also play a role in improving the taste and texture of plant-based protein. Impossible Foods' meat substitute burgers, for example, contain a molecule called heme, synthesized from genetically modified yeast, that gives them their realistic "bloody" color and meat-like taste.

Microorganism-based proteins, however, have a way to go before they fully reach taste, texture, and cost parity with conventional animal proteins. At present, for example, the cost is still two to three times greater than that of conventional proteins, especially for precision fermentation. The greatest potential for cost reductions will come through progress made in the first two steps—sourcing and growing the right organisms—a view confirmed by our survey participants (see Exhibit 9):

1. **Increasing Metabolic Efficiency.** Improving the efficiency with which microorganisms convert their feedstock into protein is key to reducing costs. It can be optimized by choosing the right strains and adjusting the conditions under which they are grown. Depending on how the mixture is stirred and aerated and on the combination of nutrients that support the process, microorganisms can be induced to make much more protein from fewer inputs in less time.

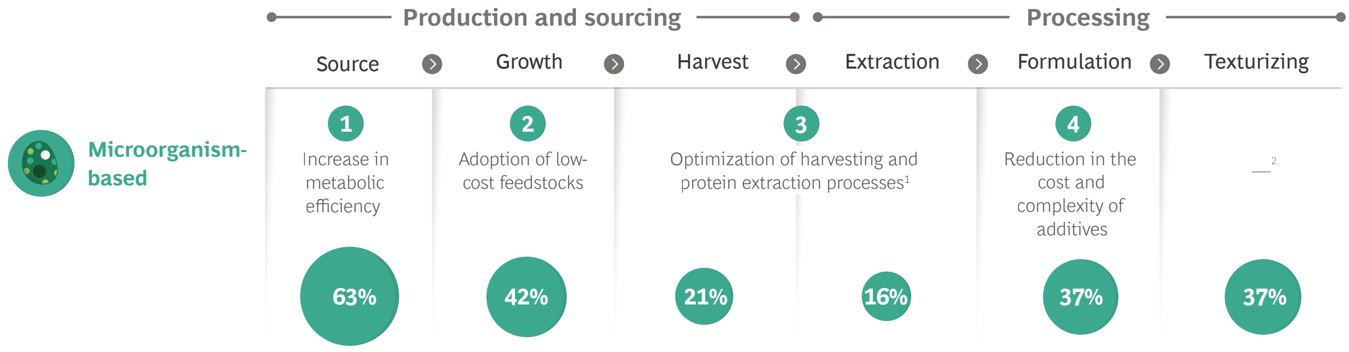
   Increasing metabolic efficiency can also have a big impact on taste and nutritional value by speeding up the production of protein while slowing the creation of unwanted outputs such as off-flavors.

> **Kevin Brennan, Quorn's ex-CEO, summarizes the challenge as follows: "It took us six weeks to find the right microorganism and 20 years to get the process to work reliably at scale."**

2. **Adopting Low-Cost Feedstocks.** A major factor in bringing down the cost of microorganisms involves finding a carbon feedstock that is less expensive than the glycerol and glucose commonly used today. Scotland's 3F Bio, for example, is experimenting with growing microorganisms on byproducts from other processes, such as ethanol production. Using a byproduct as feedstock for fermentation not only lowers cost but also opens up the possibility of even greater sustainability than plant-based proteins. "If sustainability is your long-term game," says Brennan, "then fermentation is the future."

3. **Optimizing the Harvesting and Protein Extraction Processes.** For precision fermentation, multiple steps are required to get from a suspension to a protein extract, including centrifugation, filtration, and drying. Improving and scaling up these processes—using efficient filtration membranes requiring less maintenance and less water, for example—can substantially reduce production costs. As Alex Berlin, the founder and CEO of SolarBiotech, explains, "Decreasing the cost of these liquid-solid separation steps is a major lever for alternative-protein companies, and there is room for startup technology disruption here because this is an oligopolistic industry segment with technologies that have not evolved in decades."

Exhibit 9 - Experts See the Greatest Potential for Value Creation in Sourcing and Growth Conditions



Question: For which value chain steps in the alternative-protein space do you see high potential for differentiation and value creation (e.g., significant technological development, improvements in product characteristics)?

Multiple answers were possible. Bubble size shows the proportion of respondents selecting each value chain step (N = 19 experts answered this question).

Note: The list of measures is not exhaustive, focusing only on the measures with the greatest impact.

[1]Applicable only to precision fermentation.

[2]Additional texturizing may be needed when using precision fermentation; the challenges are similar to texturizing plant-based proteins.

4. Reducing the Cost and Complexity of Additives. As with plant-based alternative proteins, low-cost so-called "clean label" functional additives must be developed to reach taste and texture parity. Experts agree that such additives are scientifically possible but need to become more practical and much less expensive. "Take making cheese that is similarly stretchy on pizza, with protein and fat and all," says Dayal Saran, the former head of R&D at Motif FoodWorks. "We are analyzing fat replacements and proteins from all sorts of animals to identify the ones that are both easy to produce in microorganisms and shelf-stable—from sturgeon eggs to camel milk and everything in between."

While improvements in additives will have only a minor effect on cost, they are essential for microorganism proteins to gain parity in taste and texture.

Animal-Cell-Based Alternatives

> Animal-cell-based alternatives need more efficient growth in much less costly media and better ways to replicate key non-muscle elements of the meat experience.

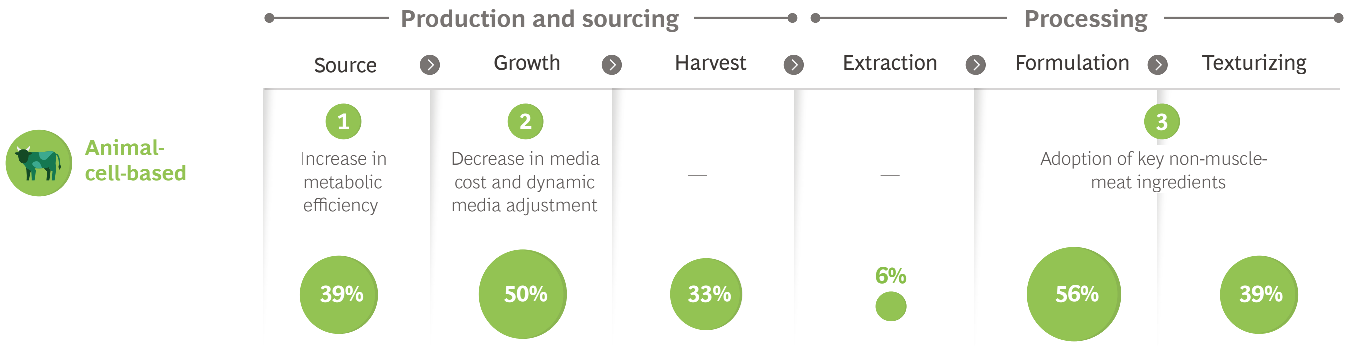
Products grown directly from animal cells, including "cultivated" meat and seafood, are already beginning to appear on the market, although it will take years before they reach parity with conventional animal proteins. The first test restaurant for SuperMeat's cultured chicken recently opened in Israel, and Eat Just has received approval to sell its cultured chicken in Singapore. Other companies around the world are hot on their heels, currently testing a variety of products. The cost of making cultured meat is still at least an order of magnitude above that of conventional meat, however.

The technology for making animal-cell-based alternative proteins is transformative. A few cells are taken from a living animal—for instance, a cow or a certain species of fish—and then grown in a nutrient-rich medium in a tank, producing thousands of kilograms of that species' flesh.

Animal-cell-based alternative proteins are the next logical step in how agriculture has changed over the centuries, from having a single cow in your backyard to farming animals at factory scale to a factory farm without the animals. Indeed, some companies are planning to produce animal-cell-based meat in what is essentially a large farm, with multiple bioreactors next to one another, like cows in a barn.

We expect animal-cell-based meats and seafood to approach parity in the early 2030s. To get there, growing cells efficiently and getting the taste right through formulation will prove the greatest challenges—and provide the most value, according to experts (see Exhibit 10):

Exhibit 10 - Experts See the Greatest Potential for Value Creation in Optimizing Animal-Cell Growth and Formulation



Question: For which value chain steps in the alternative-protein space do you see high potential for differentiation and value creation (e.g., significant technological development, improvements in product characteristics)?

Multiple answers were possible. Bubble size shows the proportion of respondents selecting each value chain step (N = 18 experts answered this question).

Sources: Industry survey of 59 experts, conducted by Blue Horizon and BCG, November–December 2020; Blue Horizon and BCG analysis.

Note: The list of measures is not exhaustive, focusing only on the measures with the greatest impact.

1. **Increasing Metabolic Efficiency.** As with micro-organism-based alternative proteins, the speed and output of the culturing process must be improved. Selecting the right cells and optimizing the growth conditions will enable companies to reduce the cost of facilities, labor, utilities, and input material per kilogram of finished product.

   "There is a lot you can do with metabolic-efficiency optimization," says Dr. Steve Oh, the chief scientific advisor at SingCell, a Singapore-based contract development and manufacturing company for culturing meat cells. "We are looking at taking cells from young versus older animals, different tissues, and so on, to produce meat on microcarriers in suspension bioreactors. Then we can also think about modifying the cells so they produce fewer byproducts like lactate, which can become toxic to the cells if too much of it accumulates in the very high density cultures that we achieve."

2. **Decreasing Media Cost and Dynamically Adjusting Composition.** To reach cost parity, the media in which animal-cell-based proteins are cultured must become less expensive and more efficient. Accomplishing this will be the main lever to achieve cost parity.

   To get there, companies must first switch from expensive pharmaceutical-grade media ingredients, including growth factors, to less expensive food-grade ingredients; and these must also drop further in price through economies of scale in their production.

   The next step will be to use the media more efficiently, continually recycling it for reuse by removing waste products and adding nutrients. This will require delicate sensors and instruments that can adjust the media dynamically, depending on each cell type's specific needs. Many industry veterans are actively conducting research in the area.

   > **Lavanya Anandan, the head of partnerships and external innovation at Merck KGaA, in Darmstadt, Germany, explains: "We are now developing customized bioprocessing solutions such as food-grade cell culture media to achieve the cost and scale ambitions of the cultivated-meat industry."**

   The last step is more speculative but especially promising. Mosa Meat recently partnered with feed producer Nutreco to create low-cost media using plant material that has been pretreated with enzymes to feed the growing animal cells. The technology is still nascent but offers the potential to reduce cost even further. As Peter Verstrate, cofounder and chief operating officer at Mosa Meat, notes, "We are essentially trying to mimic cow digestion, giving the cells what they would get from the cow in nature."

3. **Adopting Key Non-Muscle-Meat Ingredients.** To reach parity with whole cuts of meat, animal-cell-based proteins must replicate the fibrous quality of conventional meats. This requires adding nonmeat ingredients to induce the growing cells to form fibers and meat-like fat. Overcoming this challenge will not significantly affect the cost of the protein but will help considerably in encouraging consumers to accept it.

   Fiber formation can be induced by seeding cells on so-called scaffolds: edible structures made from polymers produced in plants, microorganisms, or even texturized soy protein. Companies differ considerably in the type of scaffold they use. Aleph Farms, for example, grows its thin steak slices on a scaffold of a material it claims is "something natural and recognizable." Some companies use no solid scaffolding at all. SuperMeat grows its chicken cells in suspension without scaffolds—the cells mature into meat tissues while excreting their own natural scaffolding. Mosa Meat creates a viscous environment in which its cells should eventually be able to differentiate into the various types of muscle and fat needed to make structured meat.

   No matter what kind of scaffolding material proves to be the most effective, it seems likely that it will not be expensive.

   > **"I would be surprised if the scaffold ends up costing more than 10% to 20% of the total cost of goods sold for the finished product at the point of parity," says Liz Specht, associate director science and technology at the Good Food Institute (GFI).**

   The GFI is an international nonprofit providing ample resources for players across the food system.

   Adding fat to animal-cell-based meat is a challenge, but some companies are actively working to address this issue. For instance, Aleph Farms in Israel recently created a rib-eye steak, a cut with no bone but plenty of fat, using different types of animal cells grown in culture. The cells were "bioprinted" into the shape of the steak with a technology similar to 3D printing.

Animal-cell-based meat holds the promise of providing meat that is equivalent to animal flesh in every aspect but without slaughtering any animals. Further developments could even exceed the standards set by animal protein, by removing unhealthy saturated fat, for instance. As Paul Shapiro, the author of the best-selling book *Clean Meat: How Growing Meat Without Animals Will Revolutionize Dinner and the World,* points out: "If people ask whether I have concerns around the health effects of eating cultivated meat, my answer is the same as for conventional meat—there is too much saturated fat. But with cultivated meat, the difference is we can change that. We should strive to make something better than meat."

Expanding the Protein Market

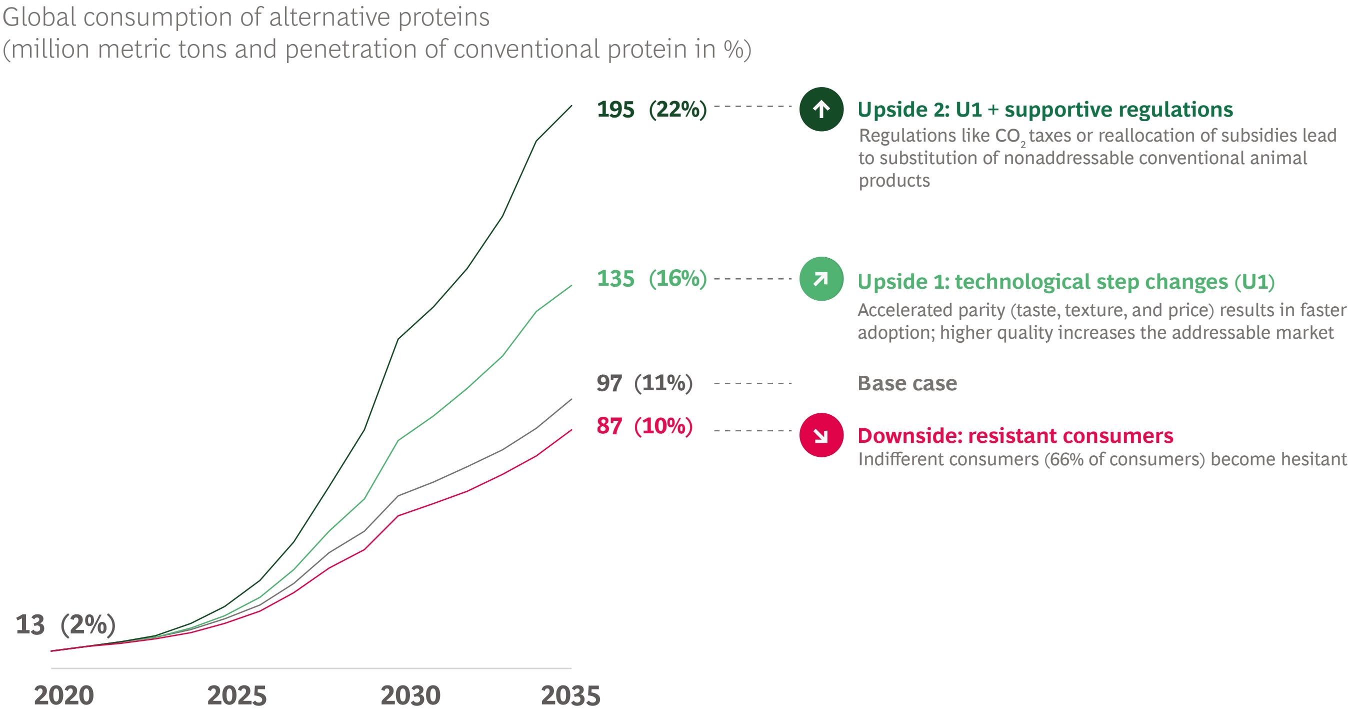
With step changes in technology and support from regulators, every fifth portion of protein could be alternative by 2035.

Our base case for the growth of the alternative-protein market needs only two dominoes to fall. The first, in motion already, is public concern for sustainability, which unites consumers, businesses, and investors in a push toward higher ESG standards and is driving the initial demand for alternatives. ESG-driven capital and consumer demand will likely tip the second domino—technological progress toward parity, as outlined in the previous chapters.

The base case conservatively assumes a consistent pattern of consumer acceptance, regulatory support, and technological change, but we explored other possibilities as well. How would changes in these assumptions affect the market's growth? Significantly, and mostly on the upside, according to the alternative scenarios we developed. (See Exhibit 11.)

In the first upside scenario, further efforts on the part of scientists, startups, incumbents, and investors tip the third domino: technological step changes, such as rapid, large improvements in metabolic efficiency thanks to better conditions for microorganism fermentation or animal-cell cultures. These efforts accelerate the time to parity of microorganism-based alternatives by a year, to 2024, and the parity of animal-cell-based alternatives by three years, to 2029. Improving fermentation can also unlock better taste, as fermentation-based "superstar" ingredients such as heme become easier and less expensive to make. As a result, alternative proteins grow more quickly, to 16% of the market in 2035.

Exhibit 11 - Alternative Proteins Could Claim as Much as 22% of the Overall Protein Market by 2035



Sources: Blue Horizon and BCG analysis.

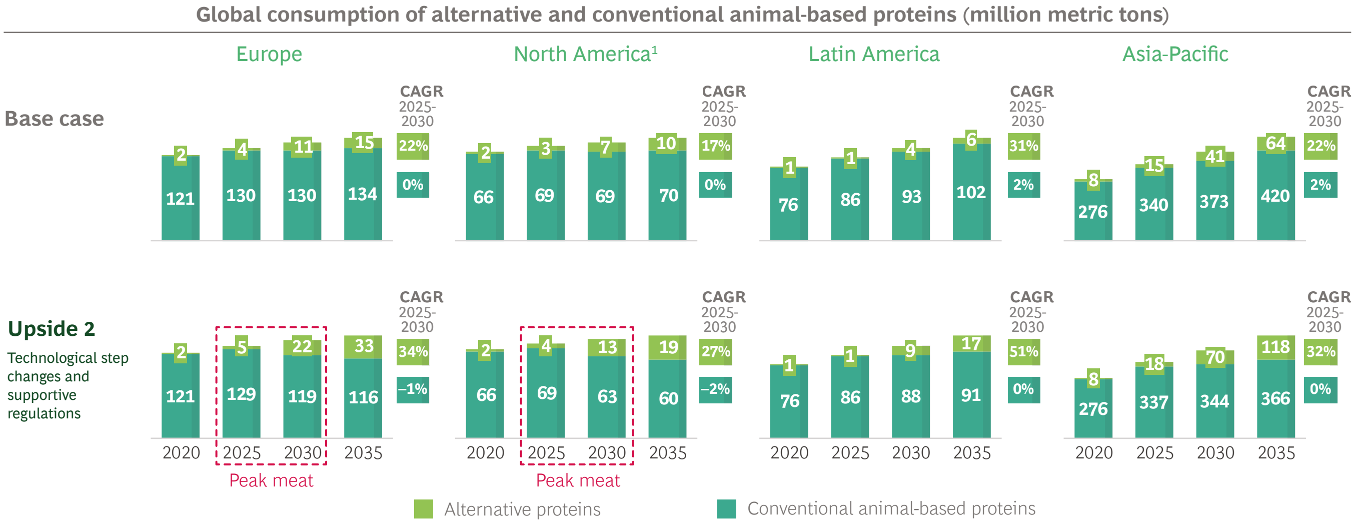
The second upside scenario requires an additional push from regulators, causing the fourth domino to fall: more supportive policies and regulations, such as widespread taxation of greenhouse gas emissions or reallocation of agricultural subsidies to support the transition to alternative proteins. (See the sidebar "Rethinking Agriculture.") Such interventions could make alternative proteins substantially less expensive than conventional animal foods. A wider price gap, in turn, would encourage consumers to choose alternative proteins over highly structured products like steak, pushing penetration to 22% of the market in 2035.

On the flip side, what happens if technological step changes and regulatory support cannot be unlocked, and consumers turn out to be less willing to switch to alternatives than the base case assumes? Even if consumers who currently say they are ambivalent about protein substitutes end up behaving like those who currently say they are unwilling to try them, alternatives would still make up 10% of the 2035 protein market.

Both upside scenarios offer the possibility of reaching "peak meat"—the point at which the consumption of conventional animal proteins begins to decrease, at least in North America and Europe. All the scenarios assume that the consumption of protein in all its forms will grow at the same rates, depending on region, from 2020 to 2035. In the upside scenarios, however, alternative proteins will make up an increasing proportion of the total protein. If all four dominoes fall, the consumption of conventional animal protein will drop in Europe and North America from 2025 onward. (See Exhibit 12.) While the growth rate of conventional-protein consumption in Latin America, Asia-Pacific, and the rest of the world will slow, total consumption will not yet decline.

We suspect that the most optimistic upside scenario could be constrained by production and distribution capacity. For instance, the scenario assumes that about 120 million tons of alternative proteins will be consumed throughout Asia-Pacific, where many people, including more than 50% of India's population, still live in rural areas and are unlikely to find alternative proteins in their local markets.

Exhibit 12 - In Upside Scenarios, Europe and North America Reach "Peak Meat" in 2025



Sources: Euromonitor; US Department of Agriculture; expert interviews; Blue Horizon and BCG analysis.

¹North America includes only the US and Canada.

Rethinking Agriculture

The world's farmers have a major role to play in the transition to alternative proteins. They must learn to grow the right varieties of the right kinds of crops, optimized for human consumption. To do so, however, they need the right environment. As Lisa Sweet, head, business strategy and engagement at the Centre for Global Public Goods at the World Economic Forum, says: "For protein diversification and a shift toward alternative proteins to be successful, the entire system needs to evolve to further support farmer livelihoods. Farmers can benefit from a closer connection to consumers, training, fair prices, and other incentives to support the transition to a sustainable, inclusive, efficient, healthy, and nutritious food system."

Most of the soybeans currently grown, for example, are not for human consumption, and production of yellow peas will need to be considerably expanded and industrialized.

Mung beans, too, need heavy investments from farmers. Such investments can be supported with longer-term contracts and price guarantees. Eat Just, a producer of alternative eggs based on mung beans, is establishing such contracts with supplier organizations. "We are getting connected deeper into our supply chain, to give farmers that assurance that there will be demand for years to come," says Madhu Sridharan, the company's vice president of product management.

Investing in Alternative Proteins: The Status Quo

The industry offers sustainable opportunities and has begun to attract significant capital.

Regardless of whether either upside scenario comes to pass, the alternative-protein arena is wide open to investors. What does the investment landscape look like? The expected base-case penetration of 11% by 2035 already implies a market that's the size of a top-50 economy—our high-level estimate of $290 billion is close to Finland's 2020 GDP. The scenario analysis shows that the base case is conservative; penetration could double to 22% if the industry has the capital and vision to make technological step changes and regulators support the transition.

Alternative proteins are penetrating a market—food—with very low exposure to recession and cyclicality, making them strongly resilient against any "unknown unknowns" that might influence the overall economy.

The demand for alternative proteins is fueled by several powerful megatrends, from health concerns to climate action and the increasing awareness of ethical issues in factory farming. It's not just about the consumer, however. Evidence is mounting that investors who take ESG issues into account can reap better financial returns. Most institutional investors already consider ESG factors when making investment decisions. In a 2020 survey of investment professionals, 85% said such issues influence their decision making, up from 73% in 2017.[6] Sustainable investing, in combination with the industry's already promising growth rates, ensures that capital will continue to flow to alternative proteins.

Substantial capital will be needed to support the growth of the alternative-protein market. Almost 30 million tons of bioreactor capacity for microorganisms and animal cells will be needed to reach the baseline case of 11% adoption by 2035. Building all these bioreactors will require up to $30 billion in investment capital—and $100 billion if all the dominoes fall, leading to a 22% share for alternatives. That's because far more bioreactor capacity will be needed if microorganism- and animal-cell-based proteins reach parity more quickly and demand for these alternatives rises rapidly. On the plant-based side, the extrusion capacity needed in the base case will require up to $11 billion, and as much as $28 billion if the greatest upside scenario comes to pass.

These high-level initial estimates do not include the necessary R&D spending or materials and operating costs of all these bioreactors and extruders. The total capital needed to unlock alternative proteins' growth will likely be much higher.

The investment community is instrumental to the success of the alternative-protein industry. Investor interest in the field is already strong, and investors are spreading their funding bets across the industry. This can create a snowball effect: as investment fuels technological progress, the demand for alternative proteins and the production facilities required to make them will increase, boosting the need for yet more investment capital.

Venture capital funding alone totaled more than $4 billion from 2015 to 2020, according to Pitchbook. Most of that—about $3 billion—went into companies pursuing plant-based alternatives, followed by $733 million in microorganisms and $416 million in animal-cell-based proteins. Development efforts directed at adjacencies such as byproducts attracted less, just $120 million through 2020.

The Investment Outlook for Alternative Proteins

Investors can leverage two plays to participate in the protein transformation.

How can investors participate in the alternative-protein market's growth? At present, most investment capital is focused on the companies offering the plant-based products that currently dominate the alternative-protein industry. These companies need to be integrated along the value chain to ensure quality control while they explore new technologies.

As alternative proteins grow from a niche product to a tenth or even a fifth of global protein consumption, however, the landscape will change, and two types of plays will emerge for investors. First, companies that solve a key technological challenge will likely become the go-to firm for that specific step along the value chain, such as flavoring, and other companies will eagerly license its intellectual property to augment their own processes. Second, well-funded companies or investors will build industrial-scale platforms for capital-intensive technologies such as extrusion.

> **"In the coming years, speed to parity will be a key differentiator," says Elizabeth Gutschenritter, Cargill's managing director, alternative protein.**

"And to get that, you need both technological developments and large-scale manufacturing platforms. The tech winners usually get the headlines, but the industry shouldn't underestimate what it will take to scale manufacturing."

Technology Plays

In this category, companies are developing technologies that offer significant quality or cost advantages in a particular niche of the value chain but are (at least temporarily) hard to replicate. Examples include:

- Developing advanced formulations and ingredients, including the manufacture of premixed binders, flavors, colors, or fats with a "clean label"—natural, healthy, and widely known—for plant- and microorganism-based products.

  This approach has triggered interest from large, expert incumbents. "We see alternative proteins as a big opportunity," says Jim Thorne, the president of Nourish Ventures and senior vice president of partnerships and strategy at Griffith Foods. "Consumers have decided that this is something they want in their diet." His company is developing strong relationships with alternative-product manufacturers, suppliers of ingredients, and academics who work on unraveling the mysteries of taste.

- Creating specialty ingredients via precision fermentation, such as the heme that Impossible Foods uses to flavor its meat substitute. This includes generalist contract manufacturers for made-to-order superstar ingredients as well as specialists that make one substance that becomes an industry paradigm.

- Forming mutually beneficial links through the development of useful byproducts, such as integrating microorganism-based protein production with bioethanol fermentation. This play can connect technologies within the alternative-protein industry and with outside industries, providing a cost advantage to both partners.

Industrialization and Platform Plays

Here, companies are aiming to differentiate through economies of scale, harnessing the high barriers to entry of capital-intensive technologies. Examples include:

- Developing and supplying food-grade fermentation and cell culture equipment such as bioreactors, measuring devices, and efficient media. The technology for growing cells in culture is not new; the pharmaceutical industry has been employing it for years. To reduce the cost of the growth process, however, the industry must shift from expensive, ultrapure pharmaceutical-grade ingredients and equipment to food-grade versions.

  Volumes must also increase drastically. Madhu Sridharan, the vice president of product management at Eat Just, puts it this way: "To make meat cost-effectively, the industry will need to grow cells in volumes equivalent to a four-story apartment block."

- Developing processes and supplying machinery for large-scale, reliable, low-cost formulation and texturizing, which the plant- and microorganism-based alternative-protein sectors will need to realize their growth potential.

- Refurbishing conventional-protein production plants and equipment to reduce capex and drive the transition from conventional- to alternative-protein production.

Challenges to Growth

As with any new investment area, success in alternative proteins requires considerable expertise. We anticipate three main challenges that investors will need to navigate:

- **Consumer Acceptance.** The industry needs to maintain consumers' interest in alternative proteins and willingness to adopt them, which could be impaired by concerns about sustainability, health and safety if regulation is perceived as too weak, or regulatory hurdles if they are too high. Investors can support work that links alternative-protein companies with suppliers, researchers, and regulators to provide consumers with safe and clearly labeled products. (See the sidebar "Regulating Alternative Proteins.")

  Securing consumer acceptance will require collaboration from stakeholders along the value chain, and it is not about to get any easier. Florence Jeantet, senior executive at Danone and managing director of the OP2B Coalition, says, "In scaling up alternative-protein production, extra care must be taken to maintain transparent, environmentally friendly, and robust supply chains. The more people reconnect with their food, the higher standards they have."

- **Competing Technologies.** Different technologies are being used in several steps of the alternative-protein production process—stem cells versus other cell types for animal-cell-based protein production, for example. Time will tell which technologies work best. Investors need deep knowledge and a broad portfolio to ensure that they invest in the technologies that become paradigms.

- **Technological Disruption.** The industry could be suddenly transformed by an entirely new technology, such as the creation of foods that are not based on agricultural inputs at all. Companies including Solar Foods and Air Protein, for example, are developing proteins produced from air, water, and electricity. If such foods become a reality, unit costs for protein could be reduced nearly to the cost of handling the final product, with almost no variable costs for the inputs required. Investors need to be aware of such potential disruptions and carefully judge which ones are likely to materialize.

> **To successfully navigate these potential challenges, investors need considerable technological understanding, direct access to key players throughout the industry, and the scale to build a balanced portfolio.**

Adequate size and strong commercialization capabilities can be a big advantage, and this is where conventional food industry players and equipment makers have a unique opportunity. Incumbents can successfully invest in alternative proteins within their own company. Indeed, several large food companies are actively exploring the space. (See the sidebar "Big Companies, Small Beginnings.")

Regulating Alternative Proteins

If alternative proteins are to reach their full potential, consumers must trust them, knowing that these foods are safe to eat and that their ingredients are clearly and accurately labeled. To that end, proper regulation of how alternative proteins are made, approved for marketing, and labeled is essential. At present, the global regulatory environment is still vague and fragmented but is developing rapidly.

In general, alternative proteins made from commonly used ingredients such as soy and peas do not require regulatory approval in the form of authorization to market and sell a specific product in a specific country. Alternatives made from novel substances such as microorganisms, or that contain an unusually high concentration of specific proteins such as mung bean protein isolate, do require approval.

Paths to approval exist for many novel foods and ingredients and genetically modified foods. In Europe, the approval process for novel foods differs from that of genetically modified foods, which are strictly limited. In the US, the Food and Drug Administration and Department of Agriculture are working on a separate process for cultured meat, but it remains unclear how other governments will act. In this context, Singapore's approval of Eat Just's cultured chicken is an important milestone.

Debates continue about proper labeling of alternative proteins across regions. On one hand, the names of conventional products, like "ham," may be protected by national or state governments, prohibiting companies from using them to describe alternative proteins. On the other hand, growing interest in requiring companies to include products' climate impact on labels could make the benefits of alternatives more transparent to consumers.

Given the current state of regulation, alternative-protein companies and their investors should closely monitor ongoing regulatory developments.

The protein transformation is just beginning to pick up speed—investors that make smart moves now could become integral players.

Big Companies, Small Beginnings

Alternative proteins are no longer a niche business. In January 2021, many food giants, including Domino's, Subway, and Starbucks, as well as global food brands such as Magnum and Heinz, launched (or relaunched) vegan products in conjunction with Veganuary, a yearly campaign encouraging consumers to eat vegan for a month.

Many are also entering the alternative-protein arena, taking small steps but taking them quickly. Vipul Chawla, president of Pizza Hut International, which put alternative meats on its menu in 2020, points out, "It's hard to judge how fast alternative proteins will grow. Most judgments we make now will be wrong. My hunch is that alternative proteins will grow faster than we think."

Meat producers are now looking to become diversified protein companies. US meat giant Tyson Foods and Germany's Rügenwalder Mühle have their own alternative-protein brands. Moreover, 40% of leading food firms, including Kroger, Tesco, and Unilever, now have dedicated teams for plant-based products, according to a report by the FAIRR Initiative, a global network of investors addressing ESG issues in protein supply chains. In addition, retailers are giving these alternatives plenty of shelf space, increasing availability and sales.

Moving upstream in the value chain, equipment makers and agricultural players are looking to profit from the growing interest in alternative proteins. Bühler, a maker of extruders, is marketing its equipment specifically for alternative proteins at scale. US agriculture giant Cargill recently announced a $75 million investment in Puris, the largest North American producer of pea protein. Puris will double production at its Minnesota site by repurposing and refurbishing an existing facility for a new pea protein plant. Cargill has also partnered with White Dog Labs to produce microorganism-based alternative proteins for animal feed.

Conclusion

The benefits of alternative proteins are clear—healthier diets, lower carbon emissions, and fewer concerns about the ethics of intensive animal farming. By 2035, alternative proteins will very likely capture 11% of the global protein market, as consumers, companies, and investors push the values of ESG and parity is reached. The upside is even greater with technological step changes and full regulatory support—a market share of 22% and the likelihood that Europe and North America will soon reach the point of "peak meat," when the consumption of animal protein will start to decline.

The industry's growth, however, depends on all three kinds of alternative protein—plant-based, microorganism-based, and animal-cell-based—reaching taste, texture, and price parity with conventional proteins. That, in turn, requires continued technological innovation regarding the alternative proteins themselves and the means to scale up production to industrial levels.

Scientists and farmers are at the heart of the transformation, providing the technological means and the quality inputs needed. Incumbent producers and startups will refine and scale production to make alternatives tastier and less expensive, securing market shares in the race to parity. Consumers will demand better-tasting alternative proteins. Investors with the right vision and expertise can fund the transformation and participate in every step of the value chain. Together, they can support the growth of alternative proteins and benefit from this $290 billion market.

The protein transformation is only just beginning to pick up speed, with more and better products to come. Investors making smart moves now could become integral players in accelerating the transition to a more sustainable food ecosystem.

Glossary

Alternative protein: In this report, we use the term "alternative protein," or "alternative," to refer to a product that can be substituted directly for a conventional animal-based product, such as meat, seafood, milk, eggs, and dairy. We do not include traditional plant-based foods such as pulses, tofu, and tempeh in our definition of alternatives.

Animal-cell-based: Refers to foods based on animal cells that are grown in cell cultures, starting from a small number of cells taken from a live animal.

Bioreactor: The vessel used to grow microorganisms and animal cells. Usually made from steel; single-use plastic bioreactors are also available but still very costly. Bioreactors come in sizes from a few liters (lab scale) to thousands of liters (pilot scale; in use by animal-cell-based meat companies today) and up to hundreds of thousands of liters (commercial scale for microorganism growth, currently used by pharmaceutical companies and for industrial-scale enzyme production). Scaling up a growth process to a larger bioreactor usually requires significant R&D since many parameters need to be adjusted, including air supply, temperature, nutrients, and the like.

Extrusion: A process used to generate fibrous texture in meat alternatives. Extruders squeeze a dough-like substance through a perforated plate or die to generate pieces of the desired shape. For production of plant-based alternative proteins, two extrusion methods are in use today. High-moisture extruders create large pieces of meat-like fibrous texture such as chicken strips. Low-moisture extruders produce small, dry granules, called texturized vegetable protein, or TVP, that can then be rehydrated and used in ground-meat products such as burgers.

Fermentation: The process of growing bacteria, yeasts, or fungi in a bioreactor. Two alternatives are in use today. In precision fermentation, cells are grown while suspended in liquid; the process is similar to those used to produce industrial enzymes for laundry detergents and medications like insulin. In solid-state fermentation, solid filamentous fungi are grown in a bioreactor, forming filaments that offer a naturally fibrous texture.

Media: The nutrient solution in which animal cells and microorganisms are grown. The composition of the media varies greatly between animal cells and microorganisms, as does the cost. The hefty price tag is due to the cost of the highly purified specialty ingredients needed, including macronutrients like sugar and amino acids, micronutrients such as vitamins, and growth factors (the signaling molecules that trigger cell growth). Growth factors are the most expensive component of animal-cell-culture media today. Microorganisms do not require growth factors, however, so their media is considerably less expensive.

Microorganism-based: Refers to foods based on microorganisms (including fungi, bacteria, yeast, and microalgae) that are grown in a bioreactor.

Plant-based: Refers to foods that are produced from plants and can be substituted directly for conventional animal-based products, such as meat, seafood, milk, eggs, and dairy. We do not include traditional plant-based foods such as pulses, tofu, and tempeh in our definition of plant-based alternative proteins.

Scaffold: A structure on which animal cells are grown to make them form muscle tissue that resembles structured cuts of meat. Can be made from many materials, including plant polymers and even extruded soy protein.

Endnotes

1. A carbon dioxide equivalent, or CO_2 equivalent (abbreviated as CO_2-e), is a measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential, by converting amounts of other gases to the equivalent amount of CO_2 with the same global-warming potential. See Eurostat's *Glossary: Carbon Dioxide Equivalent*.
2. Japan emitted 1.1 gigatons of CO_2 in 2019, according to *Japan: CO_2 Country Profile* from Our World in Data.
3. London uses 2.6 million cubic meters of water per day, according to the Greater London Authority. The shift to plant-based chicken, eggs, pork, and beef, from 2020 to 2035, could save 39 billion cubic meters of water, assuming consumption as per our market model and water use as estimated in the Blue Horizon study *Environmental Impacts of Animal and Plant-Based Food*, 2020.
4. Crimarco et al., 2020, *American Journal of Clinical Nutrition*, A Randomized Crossover Trial on the Effect of Plant-Based Compared with Animal-Based Meat on Trimethylamine-N-Oxide and Cardiovascular Disease Risk Factors in Generally Healthy Adults: Study with Appetizing Plantfood—Meat Eating Alternative Trial (SWAP-MEAT).
5. UBS, Future of Food I and Food of the Future II, 2019 (surveys of consumers who have not yet tried plant-based meat).
6. Future of Sustainability in Investment Management, CFA Institute, 2020.

For Further Reading

Boston Consulting Group and Blue Horizon have published other reports and articles that may be of interest to senior executives. Recent examples include those listed here.

The True Cost of Food
An article by Boston Consulting Group, October 2020

Environmental Impacts of Animal and Plant-Based Food
A report by Blue Horizon, October 2020

Biodiversity in Agriculture Makes Gains in the Boardroom
An article by Boston Consulting Group, September 2020

Your Supply Chain Needs a Sustainability Strategy
A Focus by Boston Consulting Group, July 2020

ESG Commitments Are Here to Stay
An article by Boston Consulting Group, June 2020

Embracing the New Age of Materiality
A report from Boston Consulting Group and the World Economic Forum, March 2020

Reviving Agricultural Innovation in Seeds and Crop Protection
An article by Boston Consulting Group, February 2020

The Dawn of the Deep Tech Ecosystem
A report by Boston Consulting Group, March 2019

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