

FOOD FOR THOUGHT

The Untapped Climate Opportunity in Alternative Proteins

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A Global Food System Transformation

What we eat has become critical in how we combat the climate crisis.

Consumers around the world want healthier foods—both for themselves and for the planet. More than 30% would fully switch their diets to alternative proteins if doing so would have a major positive impact on climate.

Consumers know and like alternative proteins, but they also want to see continued improvements in health, taste, and price. The share of consumers eating only or mostly alternative proteins would double, consumers say, if their main inhibitors were overcome. The most frequently mentioned inhibitors include health and nutrition, taste, and safety.

These are two of the headlines from a seven-market study covering North America, Europe, the Middle East, and Asia. We asked consumers about alternative protein awareness and adoption, including the inhibitors to adoption, surveying more than 3,700 consumers in seven countries. The findings point to the beginnings of a food transformation in which much of the developed world reaches “peak meat” over the next decade and consumption of animal proteins begins to decline. The impact of such a shift on our ability to combat the climate crisis and to feed a growing global population would be substantial. If the total market for animal-based products, which is responsible for 15% of global greenhouse gas (GHG) emissions, were to shift to alternatives, it would eliminate 11% of currently projected emissions in 2030. This may be the best investment opportunity we have yet seen to combat the climate crisis. A sustainable food system, with shorter supply chains, is also

a more efficient and resilient food system—a critical consideration when geopolitics turn volatile.

Assuming that the improvements come, consumers are on board. Investors are, too. Both financial and corporate investment has been driving the transformation forward, providing substantial quantities of capital along with business and technical expertise to fuel innovation and adoption. Technology is accelerating advances in both the lab and the marketplace. Regulators are actively developing new rules and systems to govern supply, safety, and security. Setbacks and barriers must be overcome, but these are to be expected with big shifts and new technologies. Think about electric vehicles: although they started off slowly, BCG now expects them to be the **most popular type of light vehicle** sold globally in 2028. The long-term trends for alternative proteins are equally positive.

This report examines the current state of—and the accelerating prospects for—alternative proteins globally, including the outlook for the market, technology, and regulation. First, we review what consumers say about their purchase intentions and the inhibitors that hold them back from repeat purchases. We examine investment trends, technological advances, and the evolution of regulation. We show why investments in alternative proteins represent an extraordinary opportunity to make high-impact progress against the climate crisis. Since the transformation will affect players along the full value chain, we then look at how the coming changes will shift roles and value pools, what their likely impact will be at each stage, and what strategic options are available to current players and new entrants. Finally, we'll examine what needs to happen to accelerate progress.

Alternative proteins present a lavish and captivating buffet. Grab a plate.

The Next Generation of Healthy, Tasty Products Stands to Win Big

76%

of consumers are familiar with alternative proteins

50%

of experienced users increased their consumption of alternative proteins during the pandemic, mainly because of greater health consciousness

+100%

is the potential increase in exclusive or near-exclusive users if the main inhibitors—health and nutrition, taste, and safety—are resolved

0%

of consumers are willing to pay a price premium at taste parity, without value added over conventional animal protein

31%

of consumers consider a major positive impact on climate as a primary reason to fully switch their diet to alternative proteins

Source: Blue Horizon and BCG Customer Survey (February–April 2022, N = 3,729).



Consumers Are Enticed

Alternative proteins have made substantial strides with consumers, who are broadly aware of the emerging food category and are favorably impressed when they try the available products. Consumers emphasize that further progress in three areas—health, taste, and price—is key to boosting demand. As Anuj Maheshwari of Singapore state investment firm Temasek Holdings points out, “It is not a given that consumers will switch to alternative proteins for the sake of climate impact, unless expectations for taste, texture, cost, and nutritional value are met.”

Despite some signs of an apparent slowdown in US sales late last year, we believe that alternative proteins remain on track for the projections we made in our first *Food for Thought* report in 2021. (See the sidebar, “Transformations Are Rarely Linear.”) By 2035, assuming that alternative proteins reach full parity in taste, texture, and price with conventional animal proteins, we anticipate that 11% of all the meat, seafood, eggs, and dairy eaten around the globe will be made from alternative proteins. With a push from regulators and step changes in technology, that number could reach 22%.

Transformations Are Rarely Linear

Transformations, especially those involving long and complex value chains such as the food system, rarely take the form of simple linear upward progressions. Setbacks occur, particularly for individual companies, as broader economic, social, or geopolitical events intervene. For example, sales of electric vehicles soared from 792,000 in 2016 to 6.75 million in 2021, but year-over-year growth for industry leader Tesla shows a much more jagged pattern. Revenue growth soared from 30% in 2016 to 75% in 2018, then stalled at 0% in 2019, then rose to 30% in 2020, before again falling to nearly 0% in 2021 and 2022.

Several North American producers of alternative proteins reported lower sales or missed earnings targets late last year, leading to a debate among analysts and industry experts over whether the results signaled a broader slowdown in the sector. Global data is hard to come by because most producers are either privately owned or part of larger public companies and do not disclose results. The category has clearly become much more competitive, and this affects each company differently. Large retailers have introduced alternative-protein house brands, siphoning sales from name brands.

We believe that the long-term industry trends continue to point upward. Our research shows that consumers are open to alternatives and like what they are trying, but also think that the products could be tastier and more healthful. They have learned to expect fast and frequent improvements from technologies such as digital and mobile connectivity. Many fermentation-based, animal-cell-based, and hybrid products have yet to gain significant market share. As companies in any new industry gain experience and expertise, prices tend to come down. And as we have pointed out previously with respect to [technology and climate change](#), disruptive technological progress and policy action occur much faster than anticipated. For example, forecasts of solar photovoltaic capacity in 2030 increased by a factor of 36 from 2002 to 2020, while projected unit costs dropped by a factor of three. Similar underestimations occurred in connection with the development of battery and wind power technology.

To be sure, alternative proteins will experience hiccups of their own, and the effects of inflation in many markets, as well as war and rising geopolitical tensions, are being felt around the world. But the underlying factors that our research highlights about the outsized positive impact of a more sustainable, more resilient food system are likely to get stronger in the longer term.



Awareness Is Broad-Based Around the World

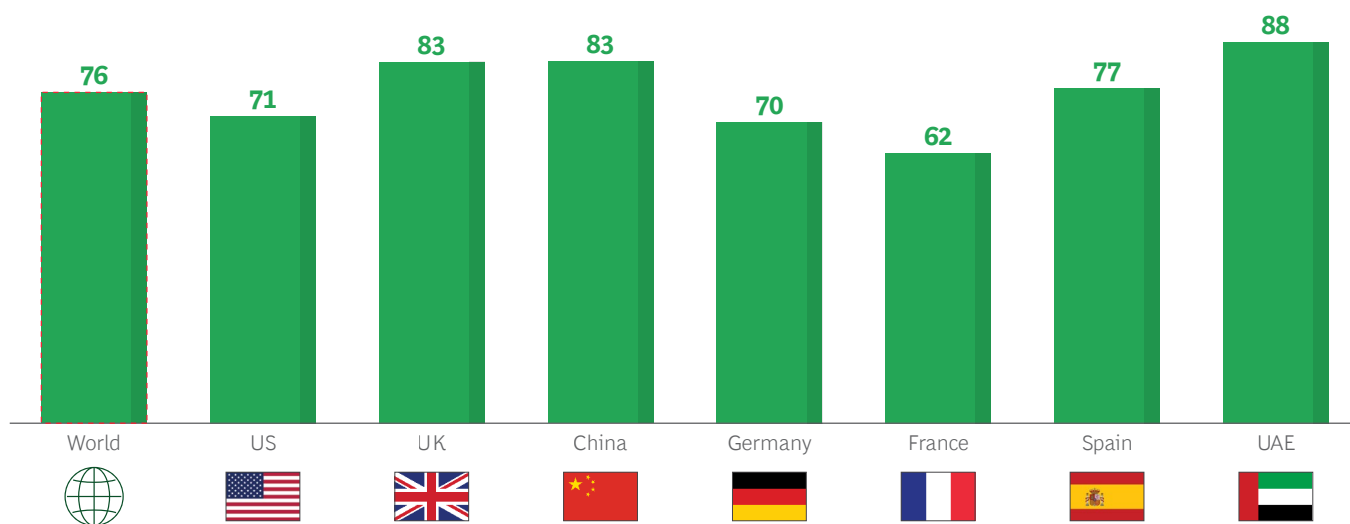
We surveyed more than 3,700 consumers in seven countries—China, France, Germany, Spain, the United Arab Emirates (UAE), the UK, and the US—on how familiar they are with alternative proteins, what motivates them to try the products, and what prevents them from purchasing and eating them more often. We found high awareness of alternative protein products across all seven markets.

(See Exhibit 1.) Plant-based proteins (at more than 70% awareness) are best known, but there is also widespread awareness of microorganism- or fermentation-based foods (especially in the UK, home to fermentation-based veteran Quorn) and animal-cell-based alternatives, both of which recorded cross-market awareness of 45%. Awareness is highest among younger consumers, higher-income households, and urban residents. (See Exhibit 2.)

High awareness translates into a substantial share of consumers who have tried alternative protein products (60%), evidence that most consumers are willing to consider the increasingly available alternatives to meat, fish, eggs, and dairy. “The biggest change that we have observed in the last two years is that people have actually started to talk about alternative proteins. There is a broad awareness today,” says David Kestenbaum of ZX Ventures, the global investment and innovation arm of AB InBev. Moreover, among those who are experienced with alternatives, 35% have become frequent, near-exclusive, or exclusive consumers. (See Exhibit 3.)

Exhibit 1 - Consumer Awareness of Alternative Proteins Is High

Share of respondents that know at least one product category (%)

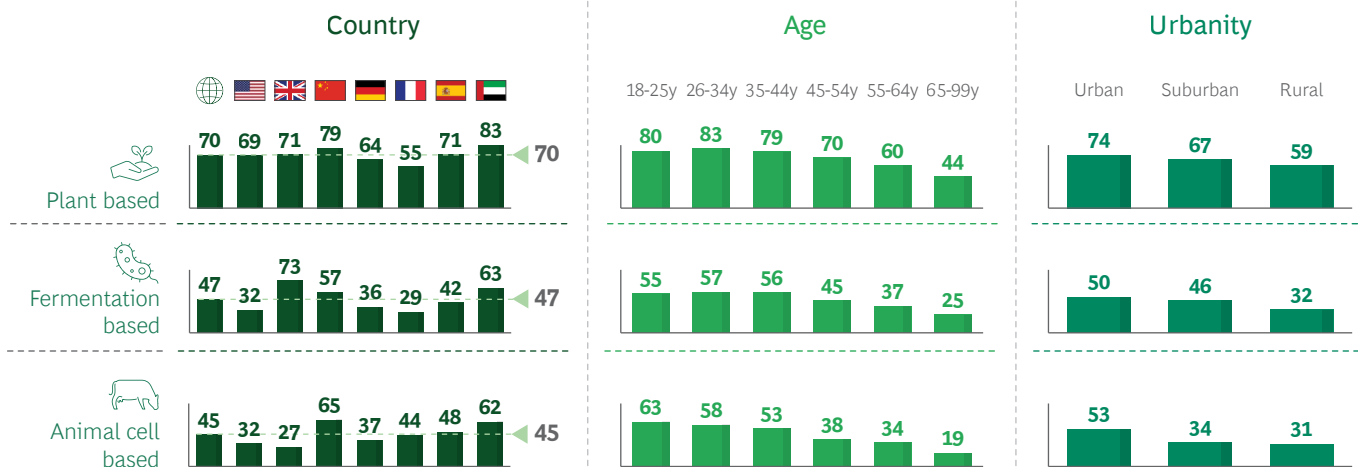


Source: Blue Horizon and BCG Customer Survey (February–April 2022, N = 3,729).

Q: Do you know or have heard of any product based on alternative proteins (i.e., animal-free products that aim to replace conventional animal-based products such as meat, eggs, and milk) in the following categories?

Exhibit 2 - Awareness Is Highest for Plant-Based Products and Decreases with Increased Age and Among Rural Populations

Share of respondents (%)

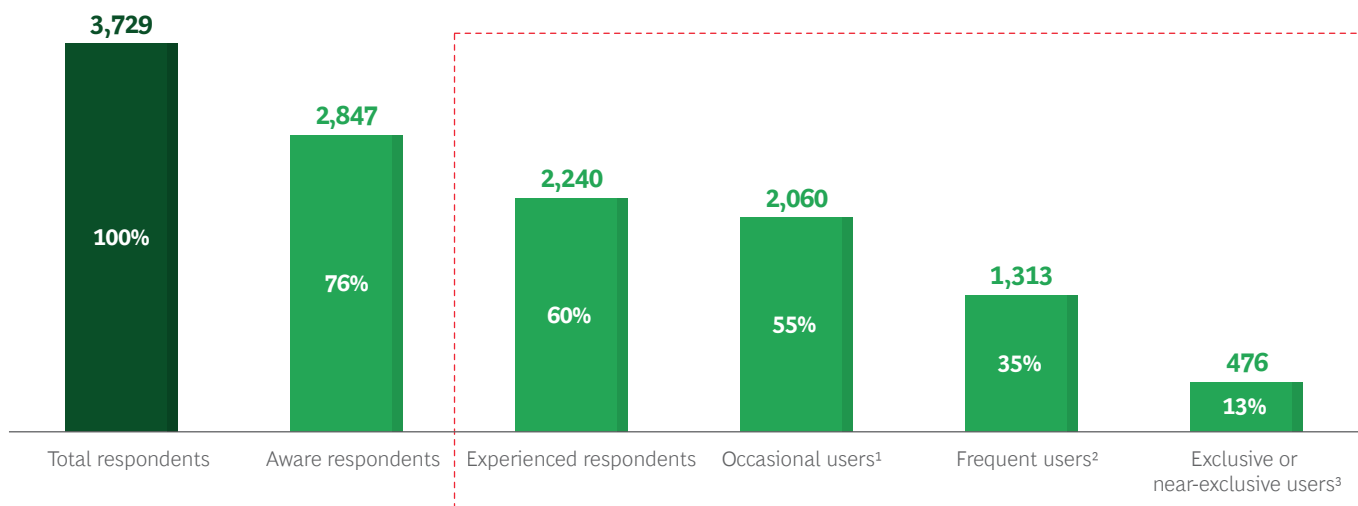


Source: Blue Horizon and BCG Customer Survey (February–April 2022, N = 3,729).

Q: Do you know or have heard of any product based on alternative proteins (i.e., animal-free products that aim to replace conventional animal-based products such as meat, eggs, and milk) in the following categories?

Exhibit 3 - 60% of Consumers Have Experience with Alternative Proteins

Number of respondents



Source: Blue Horizon and BCG Customer Survey (February–April 2022, N = 3,729).

¹At least occasionally consume alternative proteins, but mostly other sources of protein.

²At least balance diet evenly between products based on alternative proteins and other sources of protein.

³Mostly or only consume alternative proteins.

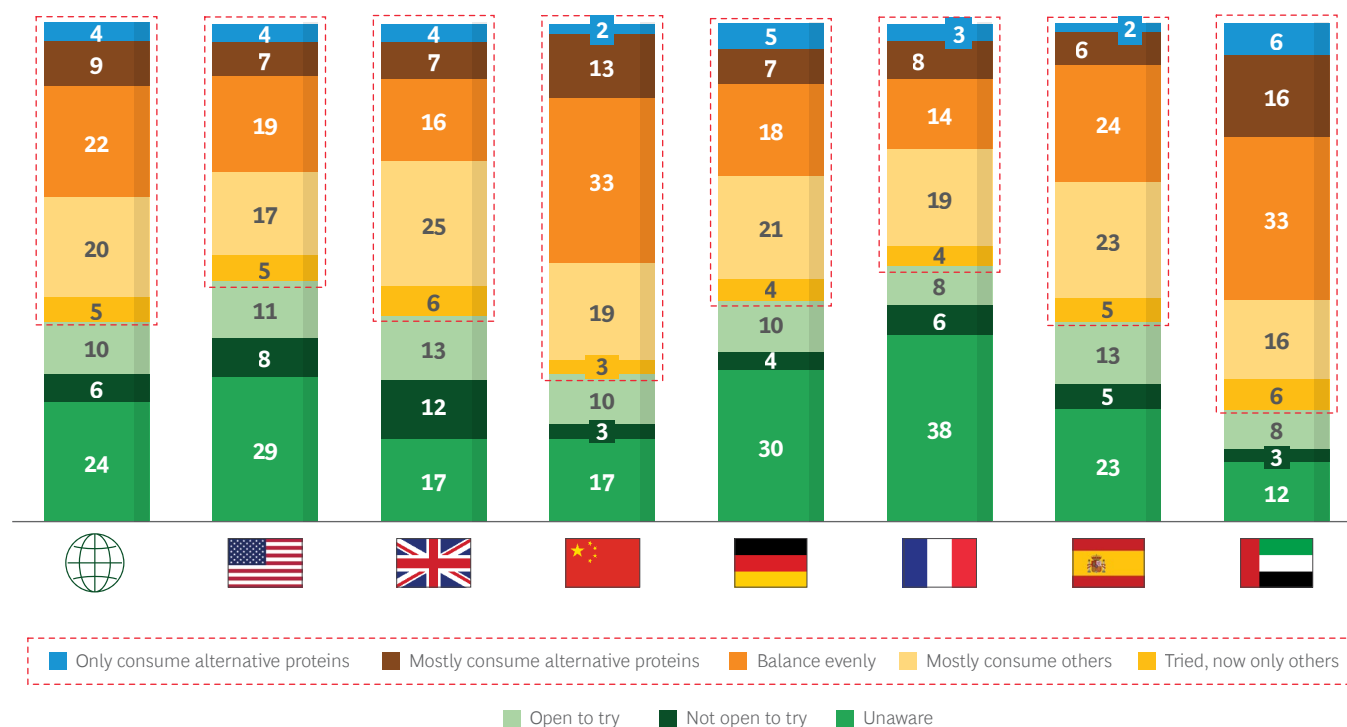
Consumption varies by market. (See Exhibit 4.) Consumers in the UAE are the most open to alternative proteins, and French consumers are the most hesitant. Almost half of consumers in China (the world’s largest market by population) have already integrated alternative proteins (including long-standing dairy alternatives such as soy milk) into their diets. As Albert Tseng of Dao Foods says, “We will not be able to prevent people in China or anywhere else from consuming more proteins. But you can convince consumers to buy the right ones. This is our task.” Eugène Klerk and Daniel Rupli of Credit Suisse put the challenge this way: “Inhibitors differ globally: In more developed countries, for example, we need to motivate consumers to switch from traditional proteins to alternative proteins. In less developed countries, we need to avoid consumers adopting traditional proteins and directly move to alternative ones.”

Three-quarters of respondents cited health as the primary motivator for shifting to alternative proteins; it was the top motivator in all markets but one.

The COVID-19 pandemic accelerated adoption of alternative proteins, and health consciousness was the most common motivator. (See Exhibit 5.) The pandemic’s impact on consumption patterns has been especially strong in China, where 63% of respondents reported consuming more, or a lot more, alternative proteins. About 30% of all respondents cited health as their leading reason.

Exhibit 4 - Consumption of Alternative Proteins Varies by Market

Share of respondents (%)



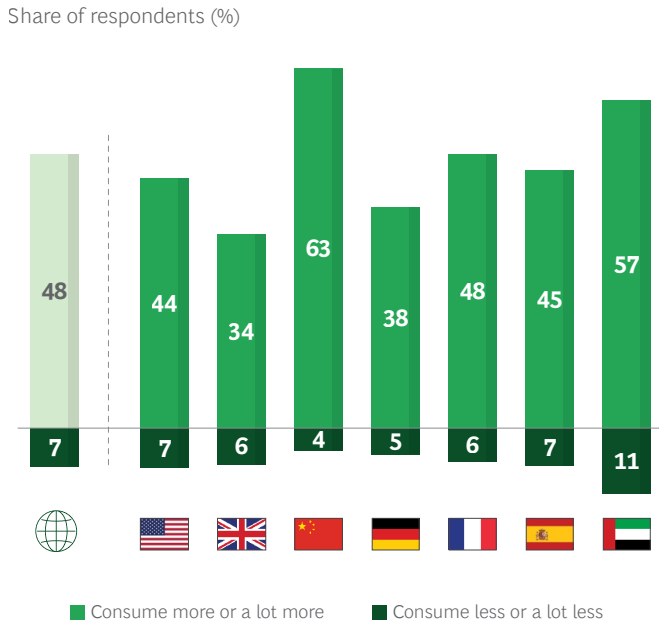
Source: Blue Horizon and BCG Customer Survey (February–April 2022, N = 3,729).

Note: Respondents had the option of choosing “Prefer not to answer,” but 0% did so in each country and globally.

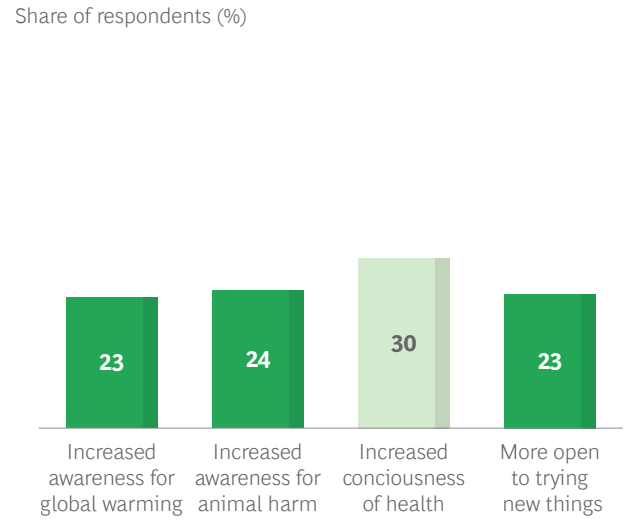
Q: What is the role of products based on alternative proteins in your diet? Please indicate how much alternative vs. other sources of proteins you usually consume.

Exhibit 5 - About Half of Those Who Have Tried Alternative Proteins Increased Their Consumption During the Pandemic

Q: How has the pandemic (COVID-19) influenced your consumption behaviour of products based on alternative proteins?



Q: Why do you consume more products based on alternative proteins since the pandemic?



Source: Blue Horizon and BCG Customer Survey (February–April 2022, N = 2,240).

Note: Chart shows responses only for consumers who are experienced, frequent, near-exclusive, or exclusive consumers (60% of all respondents).

Health, Taste, and Price Improvements Will Fuel Sustainable Consumption









Perhaps the best news of all is that consumers are finding favorite foods among the products already available. In all markets, approximately nine out of ten respondents said that they liked at least some of the products they had tried, and approximately half or more said they liked most or all such products. Consumers in most markets cited taste, nutritional value, and health as the product attributes that they appreciated the most. Yet, there is room for improvement, especially in health aspects, that can generate repeat purchases.

For those who have tried the products, the main motivators for consuming more are the desire for a healthier diet and concerns about environmental impact and animal welfare. (See Exhibit 6.) Three-quarters of the respondents cited health as the primary motivator, and it is the top driver in all markets other than France, where it is number two. When it comes to making a purchasing decision among several products, however, taste emerges as a key criterion: it is the number one factor in the US, the UK, and Germany. This may explain some consumers’ frustration with alternative proteins: they want to eat them for health and environmental reasons, but they struggle to find products that are fully satisfactory in terms of taste, health, and nutrition. (See the sidebar “Breaking Eggs.”)

Exhibit 6 - Three-Quarters of Consumers Are Motivated to Buy for Health Reasons, but Taste Is a Key Criterion in Selecting Products

Q: Why would you choose to consume products based on alternative proteins?

Share of respondents who included the answer choice in their top 3 (%)

								
Top 3 motivators to consume alternative proteins								
Healthy diet	76	78	80	80	73	60	76	80
Environmental impact	55	48	53	63	56	62	54	52
Animal welfare	55	46	59	48	72	54	64	44

Q: Please rank the following criteria according to importance when buying products based on alternative proteins.

Share of respondents who included the answer choice in their top 3 (%)

Top 3 purchasing criteria								
Nutritional value ¹	50	50	46	67	40	40	54	49
Health aspects ²	48	43	39	58	53	47	42	53
Taste	42	51	57	28	45	36	43	34

Source: Blue Horizon and BCG Customer Survey (February–April 2022, N = 2,240).

Note: Chart shows responses only for consumers who are experienced, frequent, near-exclusive, or exclusive consumers (60% of all respondents).

¹For example, has similar or better protein, fat, and carbohydrate content as compared to conventional products.

²For example, avoid antibiotics present in conventional animal-based protein.

Indeed, health concerns and taste are the biggest barriers to greater consumption across all markets. (See Exhibit 7.) If these obstacles were resolved, the share of exclusive and near-exclusive users would double. Ingredients, labeling, and transparency are additional issues. “The number of consumers worldwide seeking alternative protein products is climbing across all demographics. At the same time, consumers are also demanding less processed products, with fewer ingredients and better nutritional value,” says Ido Savir of SuperMeat. “This is the biggest challenge facing the alternative protein industry and the food industry as a whole.” Rahul Ray of Tyson Ventures, the venture capital arm of Tyson Foods, adds, “Producers need to clean up the ingredient list. Otherwise, there is a risk that consumers will step away as the products look too processed.”

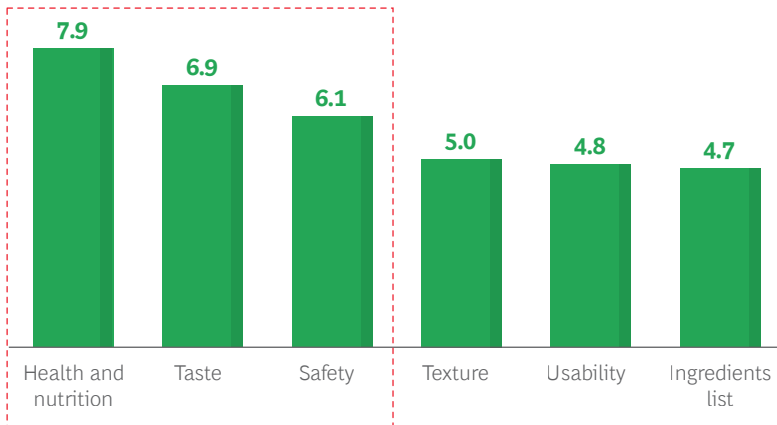
In China and the UAE, product safety is another big concern. Consumers in these markets want to see products that are certified as safe by a trusted source. When a product is successful internationally, this helps alleviate concerns about safety.

Producers also need to consider national and regional differences in diet. As Marcel Sacco of BRF observes about his home market, “Brazil is a meat country. The diet has included meat forever and it has been very affordable. People love the fresh taste of meat so ‘replacing meat’ might not be the right way forward.” “The big providers of alternative proteins in China will be domestic companies that know the local peculiarities and food preferences,” adds Nick Cooney of Lever VC, an early investor in a number of successful alternative protein startups.

Exhibit 7 - Health and Nutrition Are the Leading Global Inhibitors to Greater Consumption; Removing the Barriers Would Double Consumption by Exclusive or Near-Exclusive Users

Q: Please select the most important aspect that prevents you from consuming products based on alternative proteins more frequently.¹

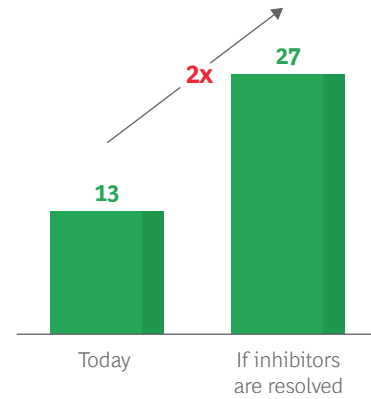
Importance score³



Inhibitors preventing experienced users from more frequent consumption of alternative proteins

Q: If the inhibitors are resolved, how would you change how much products, based on alternative proteins, you consume?

Share of exclusive or near-exclusive users² (%)



Source: Blue Horizon and BCG Customer Survey (February–April 2022).

¹Q: “Please select the most important aspect: I would consume products based on alternative proteins more frequently, if they would...” We then clustered the inhibitors by themes and took the score of the highest ranking member of each cluster.

²Consumers who only or mostly consumes alternative proteins (N = 476).

³Based on maximum difference scaling with 22 inhibitors (N = 2,240).

Diversity of diet and culture is a challenge, too. As Mirte Gosker of The Good Food Institute APAC notes, “In Asia-Pacific, one of the challenges is the region’s vast diversity, with various societal trends and food cultures. But there is also an enormous opportunity to capitalize on all the indigenous crops available that could serve as raw ingredients for alternative protein products that can serve differing expectations for taste and nutrition across the region.”

Consumers emphasize that further progress in three areas—health, taste, and price—is key to boosting demand.

Price remains a sticking point in all markets. Consumers are not prepared to pay a premium for a product that offers only taste parity. “Animal-based proteins are often understood as superior across multiple attributes,” says Lisa Sweet of the World Economic Forum. “So, in the next couple of years, if alternative proteins are able to achieve a lower price point, that could be a critical enabler to motivate consumers to switch.”

Consumers’ views on acceptable price vary, but the pattern is the same when people are grouped by characteristics other than country, such as income or concern for the environment. High-income consumers who express particular concern for the environment are no more willing to pay a premium than others. Consumers in China and Germany are the most willing to pay close to parity with conventional animal protein equivalents.

Breaking Eggs

The most challenging protein alternative may not be beef or fish or fowl but the ordinary egg. Since we eat some 1.2 trillion eggs a year (a market of more than \$180 billion in 2020 that continues to grow), finding viable alternatives is one of the emerging industry's holy grails.

Eggs are particularly challenging because they are so versatile. The egg's physical properties enable it to serve as a staple prepared in myriad ways and as an essential additive in cooking and baking. For a food scientist, the egg is the molecular equivalent of Mount Everest.

That said, base camps have been established and the climb is underway. Companies have achieved progress toward parity on scrambled, processed, and additive preparations. Scrambled egg alternatives have reached the market from JUST Egg, Zero Egg, Acremade, and Oggs. Alternatives to hard-boiled eggs are available from Migros and WunderEggs; to processed eggs, from Zero Egg and Eggcitable; and to additives, from MyEggs and Bob's Red Mill.

Consumers are slower to accept (or even try) egg alternatives than other proteins. Only 2% of the consumers we surveyed said that they purchase alternative eggs. Their biggest reasons are animal welfare (26%), price (14%), taste (12%), and shelf life (11%). More than half of consumers (depending on the egg product type) are not yet interested in purchasing alternative egg products, and almost a quarter are not aware that alternatives exist. Many feel that taste expectations are not met and that prices are too high. The two biggest challenges that scientists face are the "crack the shell" feeling that half of consumers are looking for and the replication of the taste and feel of real egg yolk.

A faster road to broader market acceptance may be through B2B applications (food producers and food services). According to our survey, 11% of food service and 17% of ingredients companies already use alternative proteins, and they are far more willing to try alternatives than consumers are. If price parity can be achieved, egg alternatives could attain 5% to 10% penetration globally in 2035.



These findings highlight the need for more cost-effective alternative protein production, of course, but they also underscore the message that if producers harbor any hope of sustained premium pricing, they must offer something more, such as added value on health. Health has multiple potential attributes, from shortened ingredient lists to improved nutritional balance, lower sodium content, and more targeted nutrients such as omega-3 fatty acids. “Price parity alone is not the goal,” says Eric Toone of Breakthrough Energy. “You need to reach better price, better taste, better nutritional values, and so forth. If you do this, you can fundamentally change the industry and get to a market share where 50% or more of consumers shift to alternative proteins.”

The bottom line? The addressable market continues to develop. Consumers in all markets express a strong willingness to shift consumption further if companies address their biggest inhibitions with respect to the products themselves. The share of respondents consuming mostly or only alternative proteins would double (from 13% to 27%), and the number of people who balance consumption between alternative and conventional proteins would increase by almost a third. If the next generation of alternative protein products is healthier than conventional animal-based proteins while delivering better taste and a lower price, they have enormous potential for greater adoption.



Investors Push for Progress

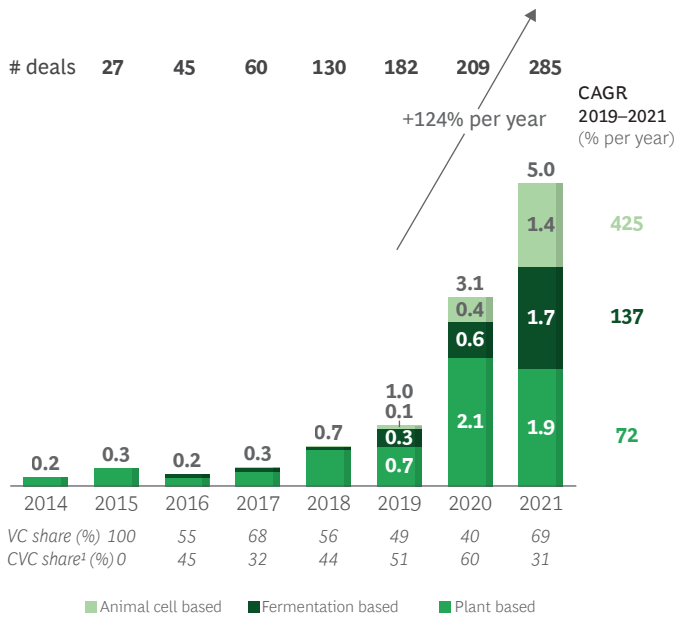
The recent pullback in tech investment has affected all types of companies, from software to synthetic biology. Alternative protein companies are not immune from such broad trends, but the transformation toward a sustainable food system is underpinned by strong secular drivers, such as the push for greater sustainability and shorter, more resilient supply chains. The more localized supply chains associated with plant-based proteins, compared with animal-based proteins, have smaller carbon footprints and are more resilient to disruptions from global shocks.

Despite recent retrenchment, investors understand the opportunity and have been pushing the transformation forward. The past year saw record capital inflows of both financial (venture fund) and strategic (corporate) capital.

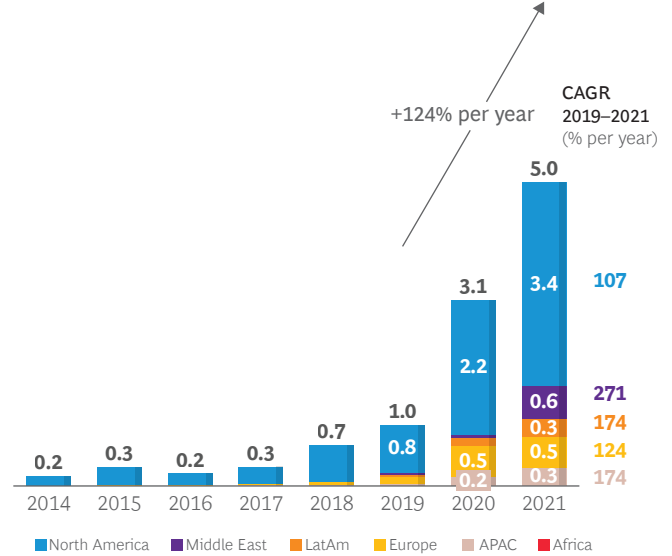
Capital invested in alternative proteins rose at an annual rate of 124% over a two-year period, from \$1 billion in 2019 to \$5 billion in 2021, according to The Good Food Institute. (See Exhibit 8.) The average deal size increased by 27%, from about \$15 million in 2020 to about \$19 million in 2021. Investment in fermentation-based and animal-cell-based companies is soaring. From 2020 to 2021, the former rose more than 150% to \$1.7 billion and the latter more than 200% to \$1.4 billion. Two fermentation-based food companies, Nature's Fynd and Perfect Day, announced \$350 million financing rounds in July and September 2021, respectively, and Upside Foods, an animal-cell-based company in Berkeley, California, raised \$400 million from Temasek Holdings and the Abu Dhabi Growth Fund. Plant-based protein manufacturer Impossible Foods raised \$500 million in November 2021.

Exhibit 8 - Funding Is Accelerating, Especially for Fermentation-Based and Animal-Cell-Based Proteins

VC/CVC invested capital by protein types (\$billions)



VC/CVC invested capital by regions (\$billions)



Sources: The Good Food Institute; Pitchbook; BCG analysis.

Note: VC = venture capital; CVC = corporate venture capital.

¹Deals involving CVC participation.

Investment is increasingly global. Middle East funding, which tends to focus on animal-cell-based opportunities, accounted for 11% of worldwide investment in alternative proteins in 2021, up from 2% in previous years. Asia-Pacific investment increased by 92% from 2020 to 2021, driven by plant-based deals.

Many traditional food companies are investing in alternative proteins.

Many traditional food companies are investing in alternative proteins. In 2020, corporations participated in about 60% of funding rounds. This figure fell to about 40% in 2021, because of rapid growth in investments in cell- and fermentation-based proteins, which—given their relative youth—typically attract more venture capital and less corporate interest. Corporations also make valuable non-cash investments. Brewers, for example, invest in startups and give partners access to their production facilities. Cargill has partnered with Enough (formerly 3F Bio) to build a commercial-scale fermented protein facility next to a Cargill plant that will serve as the feed source.

Depending on their place in the value chain, big companies pursue different investment objectives. Some invest in startups to gain a better understanding of the future implications of alternative proteins on their current business models and to de-risk and diversify. Meat giants Tyson Foods, Cargill, and JBS all have invested in cultivated meat startups, for example. Others repurpose and redeploy stranded or underutilized assets toward higher-margin and higher-growth businesses.

Some companies seek to build new business lines by leveraging initial minority investments in startups. They look to explore new processes or to take full control if the venture takes off. Some create new businesses from scratch in new markets. Thailand’s CP Foods is building its Meat Zero brand in Singapore and Hong Kong as part of a strategy to expand alternative proteins throughout Asia. Leaps by Bayer believes that alternative protein investments are core to its purpose. “We feel it is our responsibility to set new benchmarks; to find the courage to begin where others resist and to drive breakthrough innovation,” the company says on its website.

Experts see the increasing corporate involvement in alternative proteins as being both beneficial and necessary. “One of the major changes that we observe is that the industry has grown up and feels like a different ball game,” observes Liz Specht of The Good Food Institute. “Before, players were extremely protective, not transparent, and investment was largely driven by venture capitalists. Now, corporations drive significant scale. They are pragmatic and foster partnering and collaboration in the ecosystem.” Pieter van der Meche and Daniëlla Vellinga of Rabobank point out that buy-in from the large corporations along the value chain is key for startups. “Just being the disruptor in the industry is not sufficient. Corporations should be clients or partners or investors if you really want to achieve scale in alternative proteins.”

The overall growth in alternative protein investments is consistent with a broader focus on [sustainable investing globally](#), which is growing three to five times as fast as traditional investing, with a focus on solutions for the climate crisis. BCG projects that sustainable investing will account for 8% to 17% of privately invested wealth by 2026, up from 4% to 11% today. BCG research for the World Economic Forum has found that [climate leaders have achieved big gains](#) in such areas as attracting talent, cutting costs, lowering regulatory profiles, and accessing cheaper financing. The cost of capital for climate leaders in the food industry in Europe, for example, is about 70 basis points lower than for other food companies.



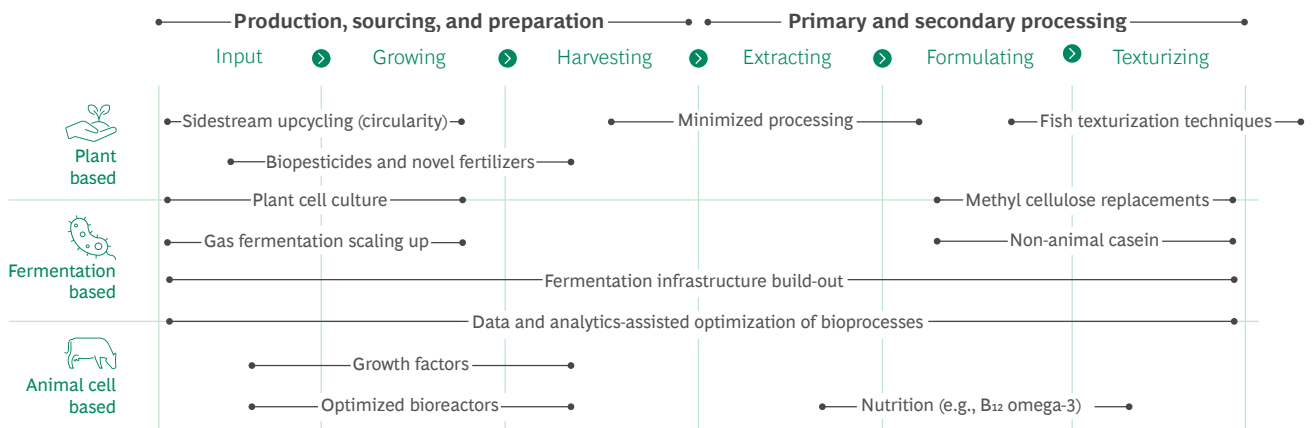
Technology Fuels the Transition— with Regulatory Support

In last year's report, we explored the possibility that step changes in alternative protein technology could generate even more market momentum, leading to earlier parity on taste, texture, and price, together with a 16% market share by 2035, up from 11% in our base case. We also argued that regulators could lend support to the transition and help boost alternative protein adoption to a market share of 22% by 2035. We have seen significant progress on both fronts.

Technology Advances

Advances in technology have occurred along the entire alternative protein value chain and are having a broad-based impact on bringing new products to market. (See [Exhibit 9.](#)) Costs are falling, bringing alternative proteins closer to parity with conventional animal proteins, and hybrid products are emerging as a way for fermentation-based and animal-cell-based ingredients to reach consumers more quickly. (See [Exhibit 10.](#))

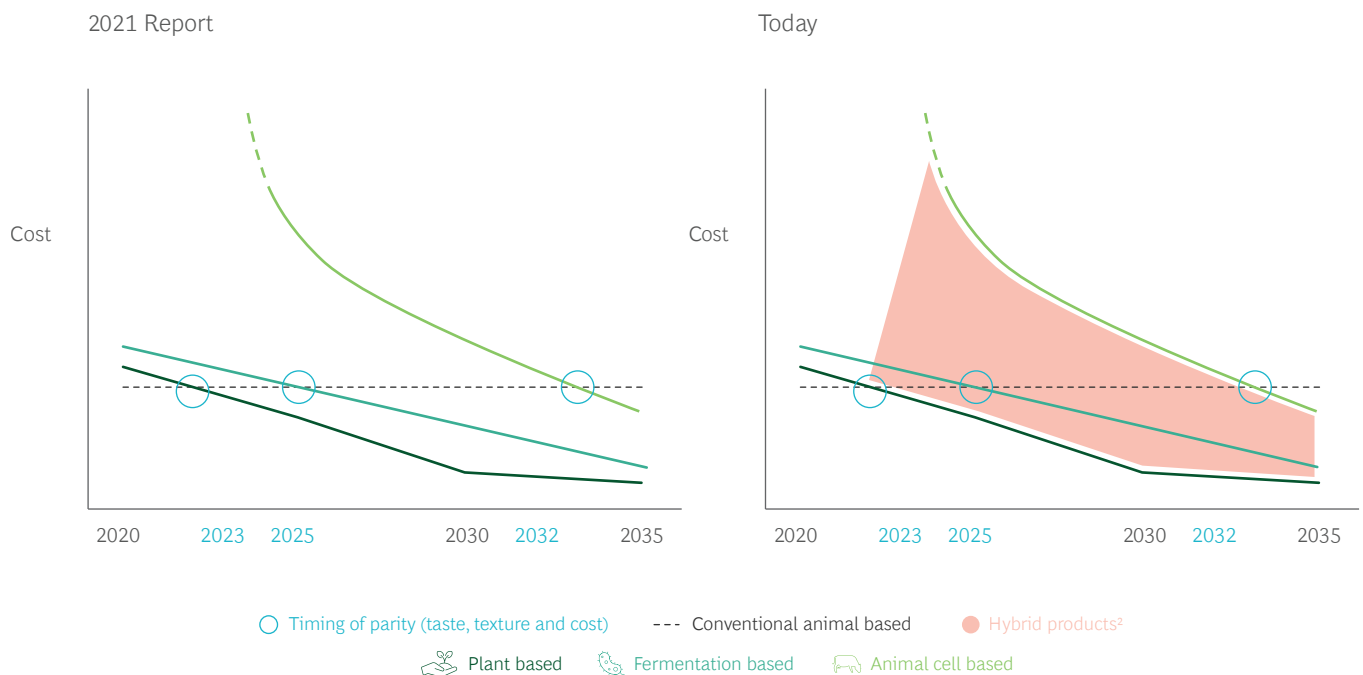
Exhibit 9 - Technological Advances Are Occurring Across the Food Value Chain



Source: Blue Horizon and BCG analysis.

Exhibit 10 - Cost Trajectories Are Progressing as Expected

Relative timing of cost parity¹ for alternative proteins with taste and texture similar to conventional animal-based proteins



Source: Blue Horizon and BCG analysis.

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

² Cost for hybrid products is highly dependent on share of animal-cell-based or fermentation-based ingredients.

Sourcing and Production. New and improved protein sources are emerging in plant-, fermentation-, and animal-cell-based foods. Plant-based protein companies are using established protein crops, such as soy and peas, and adapting inputs, extraction technologies, and final product recipes to rely less on heavily processed ingredients such as protein isolates. Isolates can sometimes be at least partially replaced with less processed concentrates or natural flours, adding nutritious fiber to the end product and lowering production costs. Roland Snel, global lead of new proteins and technology at ADM, says, “We now use soy concentrate or pea flour to improve complete nutrition and better cost in use.” Companies such as Arkeon, Solar Foods, and Air Protein are using microorganisms to produce protein straight from carbon, nitrogen, and electricity, without the need for agricultural inputs such as sugar. Solar Foods has built a pilot plant that is expected to begin production in the first half of 2023, as these gas fermentation technologies evolve from science fiction to hard-and-fast products.

Many fermentation players benefit from the optimization of microorganisms (which we referred to as *increased metabolic efficiency* in our first report), usually aided by big data and analytics. A flock of companies, including LatchBio, Officinae Bio, and EV Biotech, now offer the software support needed to optimize fermentation in food and other areas. In animal-cell-based proteins, bioreactor companies such as Unicorn Biotechnologies and Ark Biotech are developing production infrastructure specifically for cultivated meat.

As technology advances, global events present challenges for the fledgling industry. Prices for some common plant-based protein sources have spiked more than 170% during the pandemic, and food prices overall increased about 80% from January 2020 to April 2022 according to the World Bank’s agricultural food index. This trend clearly hampers companies’ ability to lower product prices. The full effects of the war in Ukraine on agricultural commodities are not yet known, though many observers expect serious global shortages. Agricultural price hikes hit animal agriculture—which converts crops at ratios of anywhere from 2 to 6 kilograms of feed for every 1 kilogram of food—even more strongly than they did alternative proteins. The BBC recently reported that farmers in the UK are predicting an egg shortage by Christmas, stemming from rising feed costs.

Rising input prices can be a boon for innovative ingredient providers as many large food producers reconsider their recipes. “I’ve had a flurry of high-profile requests to try our fat solutions,” says Andrés Montefeltro, CEO and cofounder of Cubiq Foods, which just received an investment from Cargill. “People have really started to rethink their ingredients, opening up their thinking in a way that just wasn’t there before.”

Formulation and Processing. Alternative proteins that offer health benefits and simple labeling, along with improvements in taste, texture, and price, will stand on the shoulders of the next generation of functional ingredients. Advances are under way for all types of alternative products. Companies such as Perfect Day, Better Dairy, Nobell Foods, Moolec Science, and Change Foods are using various organisms—from plants to yeasts to fungi—to make animal-free casein, a milk protein that promises to replicate melting and stretching characteristics for cheese alternatives. Nature’s Fynd has developed a palette of textures for meat and dairy substitutes by growing filamentous fungi. Companies such as Fiberstar and PeelPioneers have isolated an ingredient from orange peels that could replace the widely disliked binder methyl cellulose in plant-based meats. La Vie’s proprietary processing technology helps produce plant-based solid “fat that sizzles” and creates a bacon that puts popular dishes such as *spaghetti alla carbonara* on the plant-based menu.

Since consumers want products that they can use as easily as the original, recent innovations have focused on specific customer needs. Companies such as Plantish and New School Foods are working on different technologies to make plant-based fish that yield the flakiness of cooked salmon when grilled and sliced. TiNDLE’s alternative chicken products have a high degree of versatility designed specifically for restaurant kitchens.

Forward-looking companies are bringing potential customers into the production process early to reduce their inhibitions about how alternative products are made. Using the model that it introduced with the restaurant The Chicken, the cultivated meat company SuperMeat is in advanced discussions about establishing regional factories to manufacture cultivated meat closer to the consumer. This can help companies and brands provide their consumers with fresh products while allowing consumers to observe the production process. TiNDLE and other plant-based companies are collaborating with well-known chefs to test products with consumers.

Stakeholders must reconsider their roles and business models, gauging the transformative opportunities and disruptive threats they face.



Hybrid Technologies. Just as hybrid vehicles have helped facilitate the market transition from internal combustion engines to electric cars, hybrid alternative protein products (such as plant-based burgers that contain cultivated animal cells, or plant-based cheeses that use fermented casein) are advancing consumer acceptance of alternative proteins. Hybrid meats feel, taste, and smell more like meat. As Liz Specht of The Good Food Institute says, “With hybrid meats, the boundaries between different alternative proteins are blurring, leveraging the ‘best’ of various worlds.”

More companies are developing hybrid approaches that combine fermentation- and cell-based ingredients with plant-based products to bring them to market at prices that consumers can accept. Fermentation- and animal-cell-based proteins can add significant value in taste (for instance, fermentation-based heme lets plant-based burgers “bleed”), texture (fermentation-based casein), and health (vitamin B12 from cultivated animal cells) to the end product. The added value can be achieved at small levels of inclusion, improving the affordability of hybrid products compared to 100% fermentation- or cell-based products.

Food Systems and Bioeconomy. Advances in the technologies underpinning alternative proteins enable an entire sustainable food system, as well as the bioeconomy (the economy based on products and activities that use biological resources) beyond food. At the agricultural end of the food value chain, AgBiome uses fermentation of bacteria to produce nontoxic, highly effective alternatives to pesticides. Further downstream, ingredients such as growth factors can enable low-cost, large-scale production of both cultivated meat and cell therapies, an emerging class of medicines devoted to fighting cancer and other diseases. Companies such as Ecovative Design use fermentation of filamentous fungi (a variation on the technology used by alternative protein companies to produce meat-like textures) to produce packaging materials.

Wider Social Impact. The beneficial effects of alternative proteins on climate and animal welfare are widely reported, but these products can also have a wider societal impact. Biomilk wants to help parents who struggle with breastfeeding by offering human-cell-based breastmilk that provides important human-inherent nutrients to babies. California Cultured is producing an “ethical chocolate” to target the societal problem of child labor by producing cocoa from plant cell cultures. The new chocolate also reduces deforestation.

Several companies are bringing a circular-economy approach to alternative proteins. Kern Tec is turning heretofore unused ingredients, such as fruit stones with high cyanic acid content, into a variety of products. This innovation promises to improve the sustainability of multiple industries, including cosmetics, food, and abrasives. Similarly, Polybion converts unused materials into vegan leather, thereby reducing CO₂ emissions, avoiding animal use, and eliminating waste.

Regulatory Support

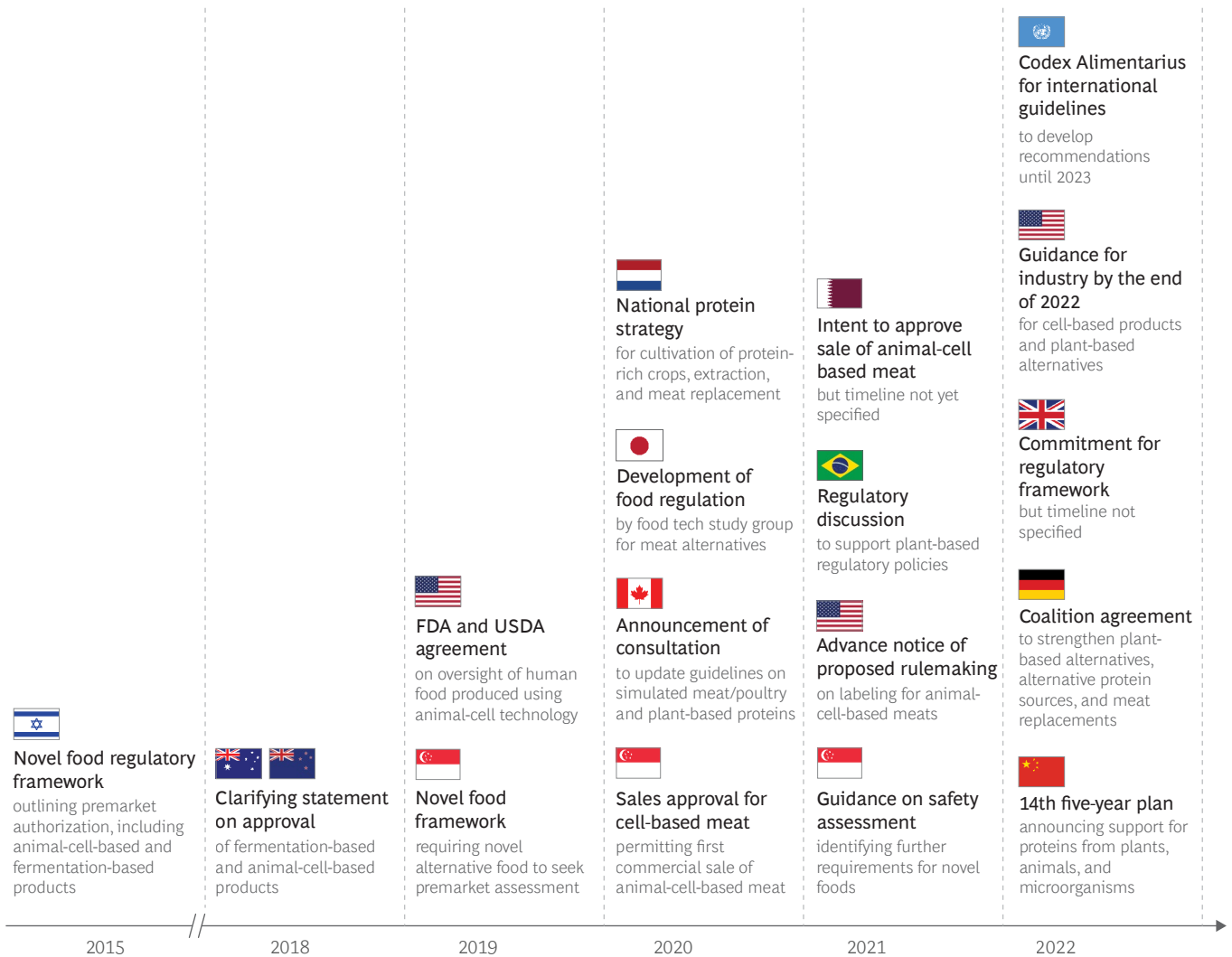
Consumers and companies alike look to regulators for rules governing the safety and accurate description of new products, especially foods. As controversies persist over such issues as approval of genetically modified organisms (especially in Europe) and product labeling (whether alternative meats or milks can be labeled “meat” or “milk,” for example), sensible and effective regulation will play a critical role in ensuring that the sector delivers safe, healthy, and transparent food to consumers, despite the rapid pace of innovation. Governments have made significant progress on this front.

Fermentation- and animal-cell-based proteins can add significant value in taste, texture, and health.

Since 2015, when Israel announced that its novel framework for regulating food safety would apply to alternative proteins, other regulators worldwide have followed suit, setting up programs that address issues ranging from biotech hubs (Middle East and Singapore) to the evolving needs of startups (US and Israel), from resource scarcity and supply security and independence (Middle East, Singapore, and China) to protein deficiency (India), and from food safety (China) to climate goals (Europe). (See Exhibit 11.) Approval procedures for plant-based products are generally well established, and procedures for fermentation-based and cell-based products are accelerating. Here are some examples:

- After defining its first requirements in 2019, Singapore issued clear approval guidelines for animal-cell-based alternatives in 2021 and has since approved several products, fueling interest in alternative proteins in Asia-Pacific. “Singapore has created a very positive environment and regulations for promoting entrepreneurship in high-tech for alternative proteins. We expect other APAC countries, such as China, to follow with positive regulations,” says Nick Cooney of Lever VC.

Exhibit 11 - Regulatory Support for Alternative Proteins Has Accelerated



Sources: The Good Food Institute; FAIRR; official government regulations; Blue Horizon and BCG analysis.

Note: Selection only, not exhaustive.

- In the US, where the Department of Agriculture regulates meats and the Food and Drug Administration oversees plant-based alternatives, the two agencies are jointly developing regulations for animal-cell-based products. In concert with previous Generally Recognized as Safe (GRAS) approvals for fermentation-based food, this regime is expected to lower barriers for new products.
- Japan created the Association for Cellular Agriculture in 2020, bringing together businesses, industry groups, government agencies and officials, academics, law firms, and the media to define industry guidelines and offer recommendations on cellular agriculture.

- In Europe, the Netherlands included animal-cell-based meat in the country's national protein plan in 2020, and more recently the Dutch parliament approved cultivated meat tasting. Likewise, Germany announced in December 2021 that it wants "to strengthen plant-based alternatives and support the regulation and admission of innovations such as alternative protein sources and meat replacements in the European Union."
- China's latest five-year plan, released in January 2022, made animal-cell-based meat and other alternative proteins, such as plant-based eggs, part of the country's food security strategy. President Xi underscored his support for domestic food innovation in a speech in March 2022, saying, "It is necessary to expand beyond traditional crops, livestock, and poultry to more abundant biological resources, develop biotechnology and bioindustry, and obtain calories and protein from plants, animals, and microorganisms." According to Nick Cooney of Lever VC, "The positive voices and integration of alternative proteins into China's five-year plan will be a game changer for alternative proteins, and it will have a ripple effect in APAC. We have already observed a shift with entrepreneurs in China that are now more passionate and actively moving into this space."

Approval procedures for plant-based products are well established, and procedures for fermentation-based and cell-based products are accelerating.

Nongovernment stakeholders are active, too, pushing to establish standards and share guidance on alternative proteins. These groups include NGOs such as The Good Food Institute and New Harvest, industry associations such as Cellular Agriculture Europe (founded in 2020) and the APAC Society for Cellular Agriculture (2022), and international agencies such as the UN Food and Agriculture Organization.



A High-Impact Climate Opportunity

Consumers' interest in alternative proteins could not come at a better time. Reducing animal agriculture in the food value chain is one of the highest-impact solutions to the global climate crisis. The positive impact it can have on GHG emissions ranges from significant (the equivalent of decarbonizing 95% of 2019 aviation industry emissions) to astounding—a reduction of 6.1 gigatons by 2030, or 11% of the 55 gigatons of emissions projected to be released in 2030 in the UN's current-policies scenario. And compared with other solutions, such as flying less or retrofitting existing housing stock, it requires relatively small economic and consumer tradeoffs. Our survey shows that consumers understand this: more than 30% of consumers consider having a major positive impact on climate to be a primary reason to switch to alternative proteins.

A 55-Gigaton Problem

As indicated above, the UN has projected that 55 gigatons of GHG emissions will be released in 2030, absent any change in current government policies. The global food system is a major part of this problem—and it can be a big part of the solution. As Lisa Sweet of the World Economic Forum observes, “Protein diversification has to play a significant role. The protein shift is a huge opportunity for tackling climate change.”

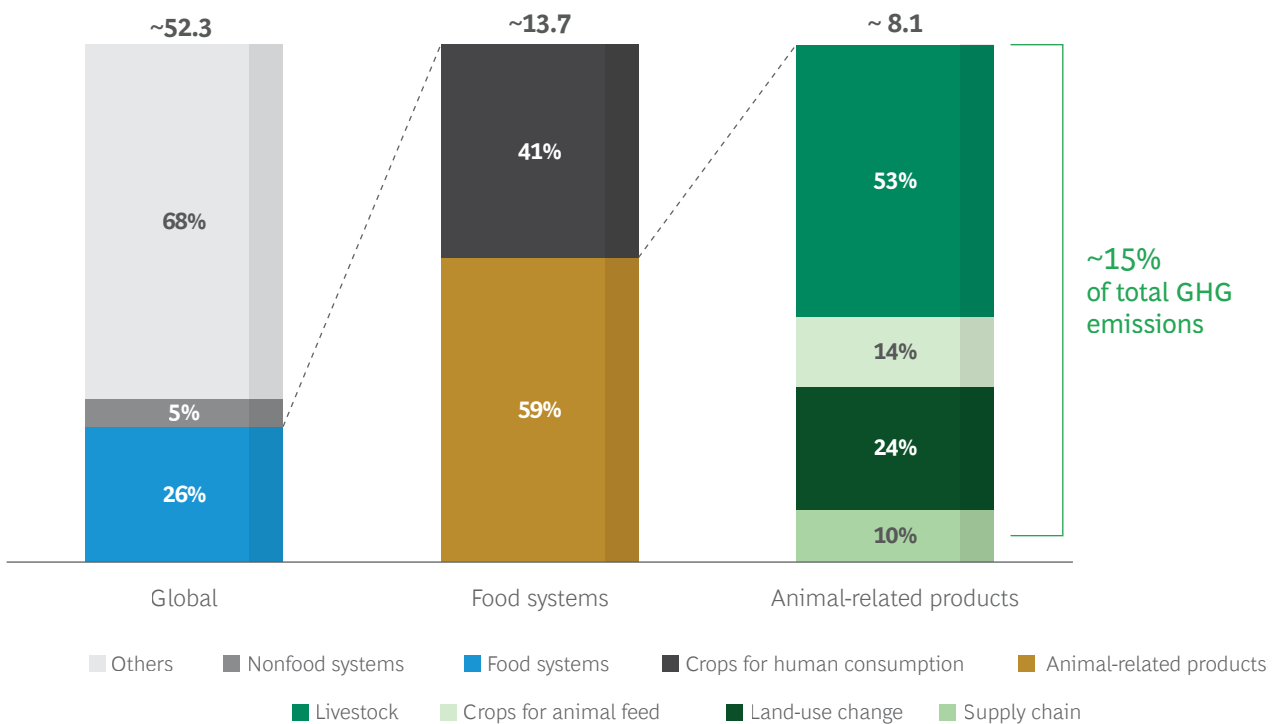
The food system accounts for 26% of current global GHG emissions, and animal agriculture is the largest GHG emitter within the food system, responsible for 15% of global emissions—roughly the same percentage that the transportation sector contributes. (See Exhibit 12.) The impact of animal agriculture is also evident in other major disruptions in our ecosystem. For example, the UN Food and Agriculture Organization estimates that land-based agricultural expansion is driving almost 90% of global deforestation. Industrial fishing and fish farms have had an adverse impact on marine life: a study in *Nature* in 2003 reported that we had already lost more than 90% of all large ocean fish since the 1950s, and a 2021 article argued that overfishing is the primary cause of ocean defaunation. The damage done by animal agriculture will surely increase as income levels rise in many developing countries, given that economic development has historically led to increasing protein consumption.

An Exceptional Opportunity...

From the analysis we did for our first report, it appears that by 2030 the shift to plant-based beef, pork, chicken, and egg alternatives will save about 0.85 gigaton of CO₂ equivalent (Gt CO₂e)—equal to decarbonizing about 95% of the shipping industry or about 22% of the building industry. (See Exhibit 13.) In our upside scenario, in which alternative proteins take 22% of the market, we see decarbonization of 2.2 Gt CO₂e by 2030, or 4% of emissions projected under the UN’s current-policies scenario.

Exhibit 12 - The Global Food System Accounts for About 26% of Global GHG Emissions, with Animal-Related Products Responsible for About 15%

Global GHG emissions in 2010 (Gt CO₂e)¹



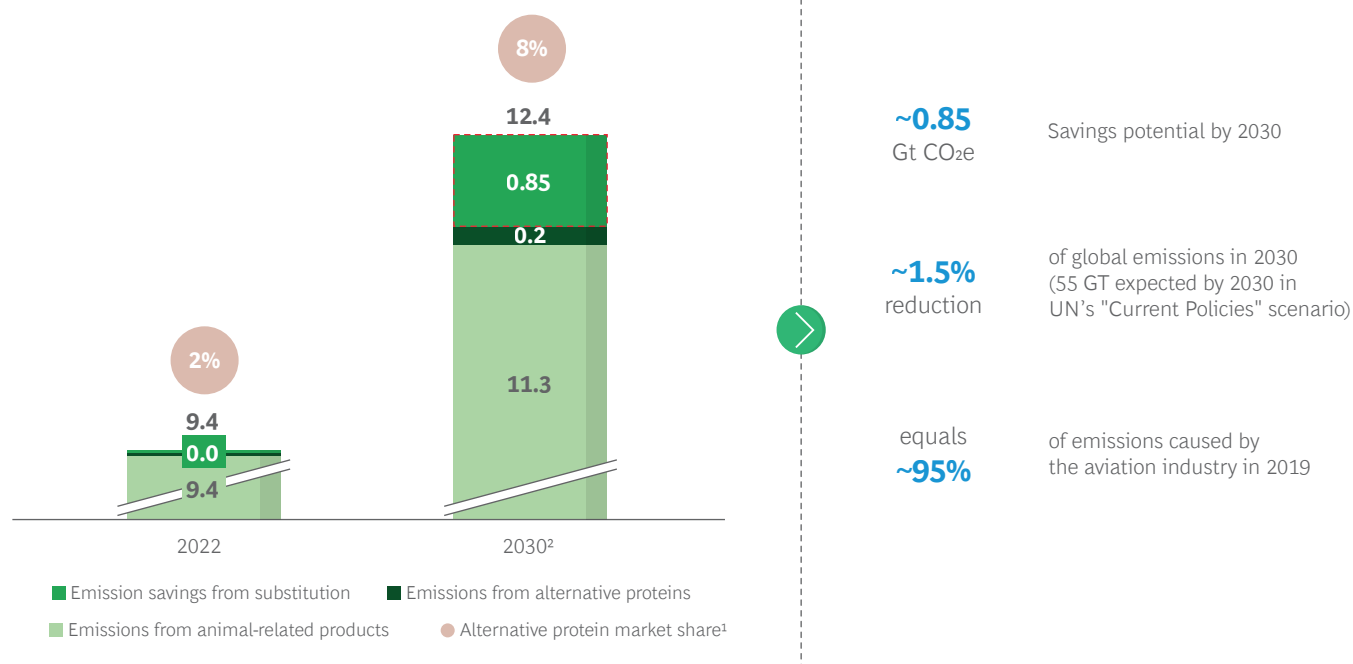
Sources: Poore and Nemecek 2018; Blue Horizon and BCG analysis.

¹Carbon dioxide equivalent (CO₂e) is a metric measure used to compare emissions from various greenhouse gases (GHGs) on the basis of their global-warming potential (GWP).

Exhibit 13 - An 8% Share for Alternative Proteins Can Reduce 1.5% of GHG Emissions in 2030

Emission savings potential from substitution of animal-related products with alternative proteins

GHG emissions in Gt CO₂e



Sources: BCG and GFMA report, “Climate Finance Markets and the Real Economy”; UN; Blue Horizon and BCG analysis.

¹The base case assumes that alternative proteins will represent an 11% share of total protein consumption by 2035 (as outlined in “Food for Thought: The Protein Transformation”), which translates into an 8% share in 2030.

²Based on United Nations Environment Programme Emissions Gap Report 2021.

What if plant-based alternative proteins could replace the total addressable market (TAM) of conventional animal proteins by 2030? That would reduce global emissions by 6.1 Gt CO₂e—11% of projected current emissions. This is an exceptional opportunity to have a positive impact on climate. From a macroeconomic perspective, investment in plant-based proteins has the highest CO₂e savings per dollar of invested capital of any sector. The emission savings can be translated into a financial gain when assessed in terms of the market value of avoided CO₂e emissions per dollar invested in mitigation efforts. To borrow a concept from finance, we call this *impact return on capital employed*, which Blue Horizon has coined as *IoCE*, or *impact on capital employed*. Given an estimated emissions value of \$50 to \$80 per ton of CO₂e, a TAM transformation would yield emission savings worth \$303 billion to \$484 billion. (See Exhibit 14.) The resulting IoCE of \$221 billion to \$354 billion per trillion dollars of invested capital is at least three times greater than anything corresponding abatement investments in other high-emitting sectors of the economy, such as transportation or buildings, can achieve.

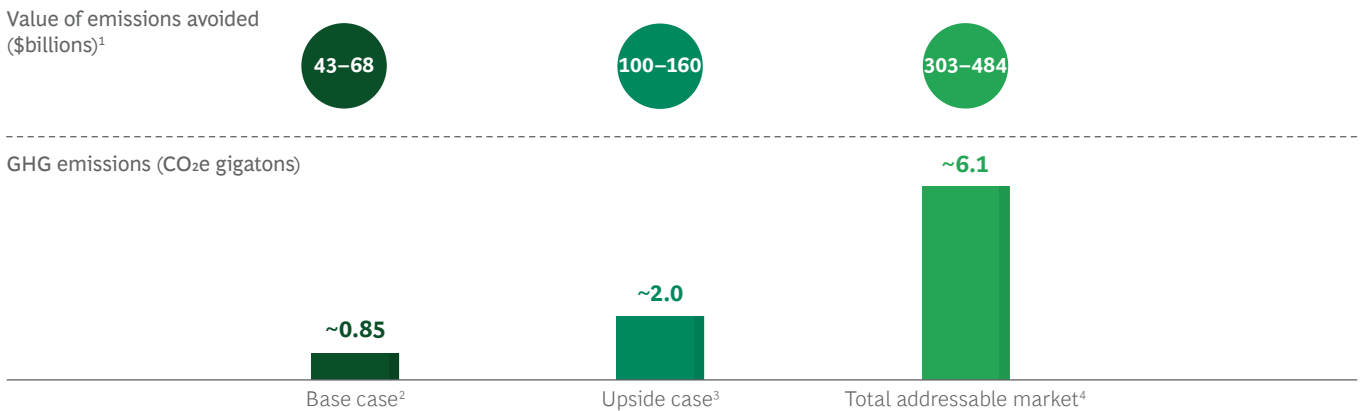
(See Exhibit 15.) Alongside gains from avoided emissions, the full IoCE of plant-based proteins also includes broader planetary effects such as water savings, as well as human and animal impact that is not quantified here. Yet despite the favorable economics and attractive potential, including ready consumer interest, alternative proteins have attracted less capital than other sectors, making the protein transformation a low-hanging fruit in the fight against the climate crisis.

...Plus a Bonus

Any change in diets toward more alternative proteins has an immediate cooling effect on the planet, since up to 50% of GHG emissions from animal farming consist of methane. Methane has a much higher global warming potential than CO₂ and a much shorter atmospheric lifetime. In addition to preventing further warming, reducing methane levels in the atmosphere comes with a cooling effect. (See Exhibit 16.)

Exhibit 14 - Alternative Proteins Have the Potential to Eliminate up to 6.1 Gigatons of Emissions, Representing Potential Savings of \$303 Billion to \$484 Billion

Emission savings potential in 2030 from replacing conventional animal-based proteins with alternative proteins



Sources: UN; BCG analysis.

¹Assuming a price of \$50 to \$80 per ton of CO₂e.

²The base case scenario assumes that alternative proteins will represent an 11% share of total protein consumption by 2035.

³The upside case assumes a 22% share for alternative proteins by 2035, driven by technological step changes and supportive regulation (both outlined in “Food for Thought: The Protein Transformation”).

⁴A 100% share of the protein market except for highly complex structures (e.g., dry-aged ribeye).

Investment in plant-based proteins has the highest CO₂e savings for invested capital of any sector.

“The urgent need is to tackle methane,” says Anuj Maheshwari of Singapore’s Temasek Holdings. “Methane-limiting technologies, such as fertilization and food waste reuse, will be among the key drivers for the food system to tackle climate change.” There are signs of change. Policymakers have begun to include the objective of reducing methane emissions on their agendas. During COP 26 last October, more than 100 governments, including the US and the EU, joined the Global Methane Pledge, which seeks to cut methane emissions by at least 30% from 2020 levels by 2030.

How Far? How Fast?

This is a big opportunity for the food sector. We estimate that attaining our base-case scenario of 11% market penetration by alternative proteins would create an addressable market of some \$290 billion by 2035, assuming demand for 97 million kilograms and average revenues of \$3 per kilogram. Investment in plant-based proteins has the highest CO₂e savings per invested capital of any sector.

Achieving a full TAM shift would require extraordinary alignment among stakeholders. Still, a substantial reduction in emissions from the broader adoption of alternative proteins is within reach. As Sir Charles Godfray of the University of Oxford put it, “The increasing urgency of climate change will make it unavoidable to have hard discussions about how diet change can support the net-zero goal.” Given the opportunity, the key question becomes, how can each player make the most of doing well by doing good?

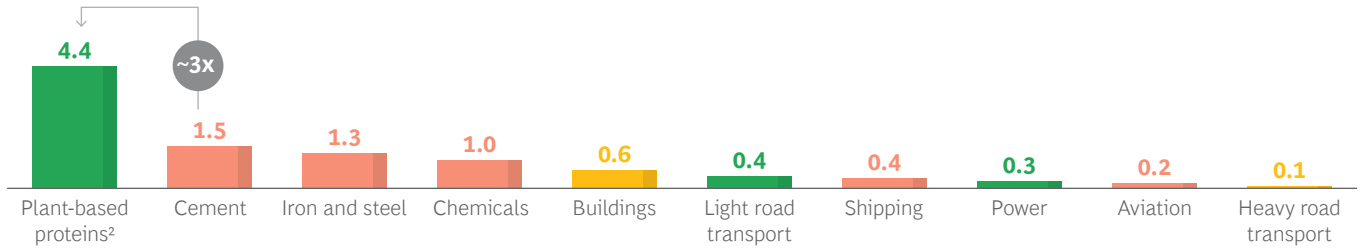
Part of the answer lies in the ability of participants in the food value chain to work collaboratively to accelerate progress. All stakeholders—farmers, food processors and manufacturers, chemicals and pharmaceutical companies, ingredients and machinery companies, food service providers and retailers, beauty companies, investors, policymakers, and regulators—have ample economic and social reason to push the transition as fast and as far as they can. As discussed in the next section, we expect all stages of the value chain to be disrupted as the transition picks up speed. Early movers will have the greatest opportunity to drive the direction and shape the disruption.

Exhibit 15 - Plant-Based Proteins Have Greater Impact on Capital Employed¹ Than Other Decarbonization Levers in All Other Sectors

Impact on capital employed (\$billions per \$1 trillion invested)



CO₂e savings (in gigatons) per \$1 trillion invested



- Mostly economic:** most investments in the sector, such as replacing animal-based proteins with alternative proteins at cost parity, are economically viable
- Mixed:** some investments in the sector, such as building automation and roof insulation, are economically viable; others in the same sector, such as moving to heat pumps in older buildings, are not
- Mostly uneconomic:** most investments in the sector, such as introducing carbon capture and storage in cement production plants (which adds costs, but no savings), are not economically viable

Sources: BCG/GFMA report, “Climate Finance Markets and the Real Economy”; BCG analysis.

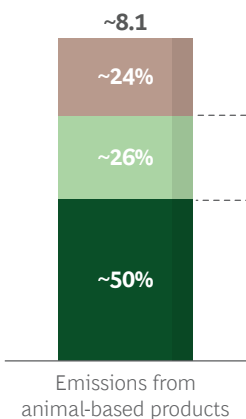
¹Impact return on capital employed (which Blue Horizon has termed IoCE, or *impact on capital employed*) assumes a market value for avoided tons of CO₂e per dollar invested of \$50 to \$80 per ton.

²CO₂e savings from plant-based products only (red meat, pork, chicken, fish, and seafood).

Exhibit 16 - The Shift to Alternative Proteins Reduces Methane, with a Positive Cooling Effect in the Near Term

Breakdown of emissions from animal-based products

GHG emissions in Gt CO₂e

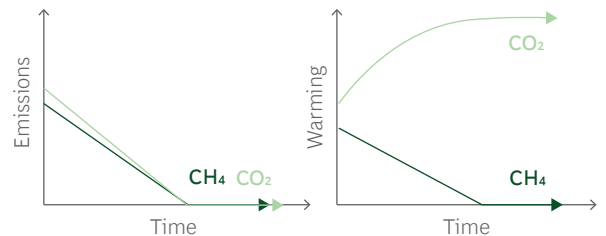


Impact on climate once emission is stopped

Atmospheric lifespan until disintegration (years)	Impact of reducing 1 Gt in comparison to CO ₂ ¹
~120	265-298x
~12	34x
300-1000	1

Cooling effect slowly starts
Slows further global warming
Cooling effect immediately starts

Estimates



Sources: FAO (<https://www.fao.org/gleam/results/en/>); The Good Food Institute, “Environmental benefits of alternative proteins”; Carbon Brief (<https://www.carbonbrief.org/guest-post-a-new-way-to-assess-global-warming-potential-of-short-lived-pollutants>); NASA Global Climate Change; IEA; Blue Horizon and BCG analysis.

¹GHG emissions are equated by using the measure of global warming potential over 100 years (GWP100—that is, the impact of reducing 1 Gt of CH₄ vs. 1 Gt of CO₂).



A Major Paradigm Shift

The transition to a more sustainable food system presents big changes and big opportunities for all food industry players, as value pools are redistributed. Decision makers should address three key questions:

- Where will most value accrue?
- What is needed to unlock that value?
- What are the risks and opportunities for farmers, suppliers, manufacturers, and investors?

As Liz Specht of The Good Food Institute puts it, “In order to make a switch to a more sustainable food system, we need better mechanisms for buyers and sellers along the value chain. This will be disruptive for a lot of players.”

The food value chain has been optimized over centuries for conventional animal protein production and efficiency, but it has become brittle in the process. Alternative proteins offer a chance to transform the parts of the global food system that are most vulnerable to global shocks, harbor the greatest health risks, and pose the biggest ethical challenges. Where producers turn higher-value crop varieties into plant-based products that are adapted to local cuisines, or where fermenters supply protein that is independent of weather conditions, supply will move geographically closer to demand. The value chain will become more localized and less vulnerable to global disruptions. The combined impact will be to redistribute where value is created—both economically and geographically.

Across different alternative protein sources (plant, fermentation, or animal cell based), value pools will move upstream toward producing and processing new protein sources, and the speed and extent of impact will depend on the type of protein (meat, fish, dairy, eggs) and the type of process (plant, fermentation, or animal cell based) involved. (See Exhibit 17.) Value pools will remain dynamic, however. For instance, the value of improved extraction methods for plant-based proteins will increase over time if new technologies enable higher functionality (a key to simpler product labels). In fermentation-based and animal-cell-based proteins, further value shifts toward improved strains and cell lines are likely if new technologies can materially reduce the need for costly carbon sources or other culture media inputs. Upstream enablers of new protein sources and products, as well as technologies that remove key bottlenecks, will realize big returns. Protein sources, ingredients, and processes that contribute to taste and texture parity or nutritional value will continue to sustain high value shares regardless of where they fall in the chain.

All stakeholders need to reconsider their roles and business models, assessing the transformative opportunities and disruptive threats that they face. The short-term risks for pharma and agtech companies, for example, are relatively low, but the opportunities could be significant if they expand their businesses to provide superior inputs for alternative proteins. Consumer goods players, which can tap into transformative opportunities if they pioneer foods that are healthy for humans, animals, and the planet, face the quickest disruption if they miss the shift. (See Exhibit 18.) On the basis of conversations with a wide range of experts and industry players, we have assessed the likely impact of these developments on key stakeholders and identified some key issues that they will need to address in response.

Exhibit 17 - Shifting Value Pools in the Food System



Source: Blue Horizon and BCG analysis.

Note: DSP = downstream processing.

Agricultural Technology

The big change here is one of purpose—from feeding animals to sustaining a new food ecosystem. Jürgen Eckhardt of Leaps by Bayer puts it this way: “Today, the seed business is largely built to feed animals. Going forward, this needs to change to supporting environmentally friendly crops at scale in order to feed humans in a more sustainable way.”

Agtech companies, which include providers of seeds, fertilizers, crop protection, and digital technologies, are key to this transition. They have significant opportunities to develop food-grade crops, increase the nutritional value and efficiency of crops, and adapt seeds for varying local growing conditions. They also face challenges, such as farmers’ need to reduce fertilizer use, especially as prices fluctuate and regulations tighten, and regulatory pressure to provide more efficient and sustainable fertilizers and crop protection solutions. Ultimately, the need for more sustainable and resilient agriculture extends far beyond alternative proteins to encompass the entire food system.

Key questions for these companies include the following:

- Which technology or combinations of technologies will enable true step changes in sustainability, resilience, and cost effectiveness in such areas as biological pest control, bio stimulants, and novel approaches to fertilization?
- Which crops will win out as inputs for alternative proteins?
- Do overlooked or prematurely dismissed opportunities still exist for certain crops, such as sea grass or flax seeds?
- How will biosafety concerns, genetically modified ingredients, and gene editing evolve and affect business models?
- How will stricter national laws and regulations on fertilization and crop protection affect the product landscape?

Farming and Crop Production

Farmers of all sizes, from families to agribusinesses, already face the enormous challenge of increasing crop production for a growing global population even as soil quality declines, abiotic stress increases, and resistance to herbicides grows. They also have the near-term challenge of managing rising fertilizer and input prices, which have been exacerbated by the pandemic and the war in Ukraine.

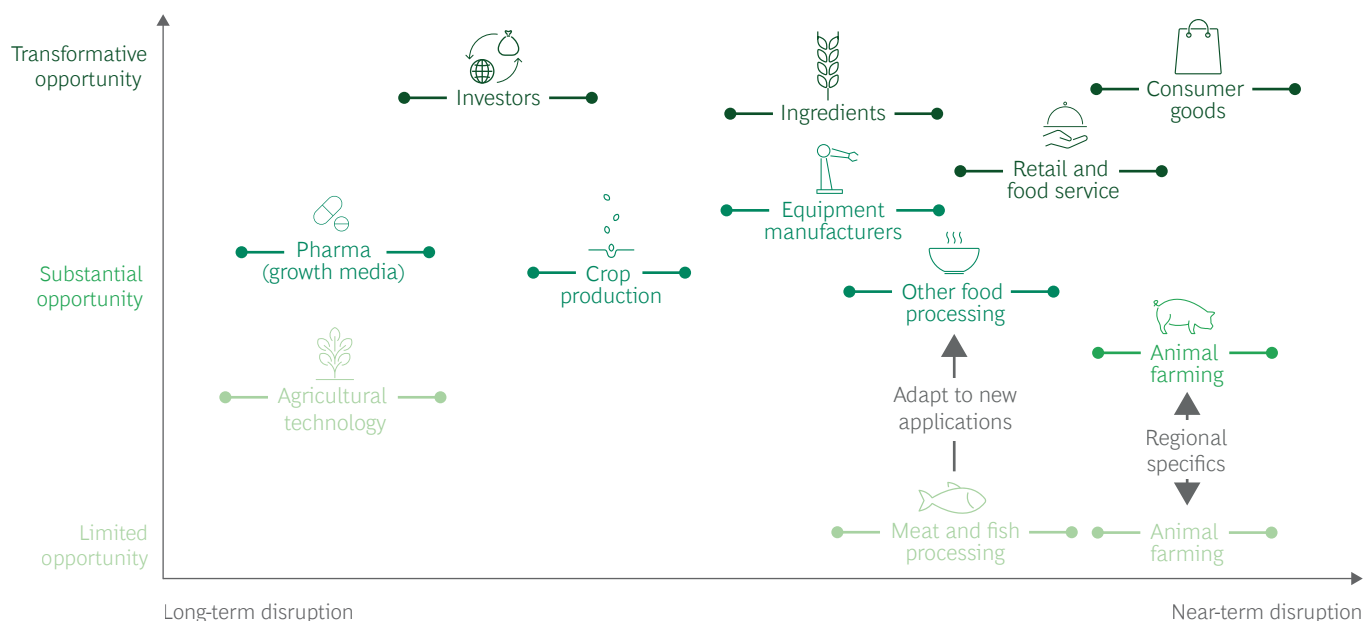
Farmers need support as they transition to sustainable practices. Today’s margins make it difficult for them to finance this major shift themselves. But they also have opportunities: growing crops locally or regionally encourages the development of more localized value chains as well as greater transparency and traceability of agricultural inputs, which can translate into better sales. Farmers can also profit from higher prices for high-value protein crops that are used directly for food instead of feed.

Key questions for crop farmers include the following:

- Should farmers switch to different crops—and if so, when—considering the required investment and risks involved in the change?
- Which crops should farmers focus on, given that some options are not yet optimized for certain geographies or growing conditions?
- What is the future role of farmers in the value chain? Do they remain growers, or should they integrate downstream, for example, into crop processing?
- Which new technologies (such as vertical farming) should they adopt?

We are starting to see sources of support for answering such questions. One Dutch agricultural cooperative, Agrifirm, with more than 10,000 members, has set up programs to offer participants services such as business development support, access to corporate partners and investors, and mentoring. These include an “agrifoodtech” innovation program that works with startup accelerators such as AgTech Garage in Latin America, StartLife in Europe, and Enterprise Singapore in Southeast Asia. “Farmers cannot just rely on what they have done for the last 100 years,” says Agrifirm’s Johan de Schepper. “They need to actively look at new technologies, such as vertical farming, sustainable agriculture, and biotechnology. This is why we are working with startups to get access to these technologies”

Exhibit 18 - The Opportunities and Risks for Stakeholders in the Emerging Sustainable Food System



Source: Blue Horizon and BCG analysis.

Animal Farming

Animal farming faces some of the same challenges from rising input prices that crop production does. In fact, the challenges can be even greater, as animals convert calories from feed to meat relatively inefficiently and, therefore, require more inputs per unit of product. In addition, regulators are increasing pressure on issues of animal welfare. For example, the EU is working on revised animal welfare labeling and legislation, which it plans to propose by the end of 2023. There are regional variations on these concerns, however. In some regions, animals have important functions beyond food (such as to provide insurance or labor), and in some cases the land they are raised on is not amenable to plant-based agriculture. To gain a comprehensive view of the subject, policymakers must conduct a full region-by-region analysis of the food system and its many social, environmental, and economic implications.

Key questions for animal farmers include these:

- Given the regional context, where do the biggest opportunities lie—in high-value crops, sustainable animal farming, or a combination of both?
- Is it possible to repurpose existing infrastructure, and if so, how can the transition be financed?

Fish and Meat Processing

So far, this segment has undergone the most disruption, as startups provide innovative products under their own brand names and consumers demonstrate their approval with their wallets. Fish and meat processors face substantial risk of further disruption, depending on the extent of consumers' shift to alternative proteins.

Banks and investors are already restricting financing for companies that they view as having unsustainable business models. An increasing number of companies, including some major players, are moving to limit their risks and establish footholds in growing industry segments. ADM and Tyson Foods, among others, have invested in Future Meats Technologies' latest funding round, which raised \$347 million in December 2021. Tyson has rebranded itself as a "protein leader." "We want to be part of the industry. We want to be part of the ecosystem," says Tyson Ventures' Rahul Ray. In Germany, Rügenwalder Mühle, founded in 1834 and until a few years ago a specialist producer of sausage and sausage products, is now generating more than 50% of its revenues from plant-based proteins, and the company is still growing.

Global players of all types need to adjust their products to local requirements and preferences. They cannot simply push foods that work in Europe or the US into Asia or Latin America, for example, where diets and traditional dishes are different. As Marcel Sacco of Brazil's BRF observes, "You need to bring the alternative proteins to the center of the plate and not push special-occasion foods. The technology is evolving, but you need to work more closely with the consumer."

Key questions for fish and meat processors include the following:

- Should companies begin to include alternative proteins in their portfolios? If so, when?
- What are the right alternative protein types to bet on? Where can the companies best leverage their assets and experience?
- What investments are needed for the transition? For example, will the move to fermentation-based proteins require building new bioreactors, or can other facilities be repurposed?
- Can the world build a sustainable food system that includes minimal animal farming? What does the role of processing businesses look like in such a system?

Other Food Processing

Another group of processors, whose current business isn't necessarily (or exclusively) animal based, but whose expertise is applicable to alternative proteins, could have substantial opportunities.

Breweries and dairy processing plants can be repurposed to help prove that the emerging industry is cost competitive and to increase scale. "Food is largely a commodity market," says Eric Toone of Breakthrough Energy. "If you want to be a winner, you have to be better at cost and scale than your competitors. This is in particular true for alternative proteins, where winners will need to have a structural cost advantage to the incumbent industry." And David Kestenbaum of ZX Ventures, AB InBev's global investment and innovation group, points out, "We do not see technology as a roadblock for alternative proteins, but scaling up production and the corresponding infrastructure. In particular, corporations need to provide long-term capital and deep expertise in infrastructure for production at scale to make parity happen."

AB InBev is taking such an approach with its startup, EverGrain. Spent grains account for up to 85% of waste at breweries and have traditionally been sold off at low prices or even given away. EverGrain has developed a technology to extract proteins and fibers from spent grains and repurpose them into high-quality, plant-protein-rich nutritional ingredients.

Key questions for food processors include these:

- What alternative-protein types (plant based, fermentation based, or animal cell based) and corresponding ingredients have the most synergy with each player's expertise and infrastructure?
- When should a company move into each protein type and new product? How can it avoid being too early and losing money and yet not be too late and fall behind early movers?
- When should it ramp up production capacity, and for which kinds of products, to ensure that when it is ready to scale, consumers will be willing to buy?

Consumer Goods

The opportunities and risks are greatest in this segment, and change will be fastest. Early-moving incumbents with the production facilities and expertise necessary to produce at scale can form partnerships that benefit both startups and traditional players. Unilever and Nestlé, for example, are expanding their partnerships with food technology companies and scaling up production of alternative proteins.

Key questions in this sector include the following:

- What are consumers' needs and intentions? Which of these are most firmly linked to secular drivers and hence most durable and most worthwhile to address with new products?
- What is the right approach to play in this market—branded products with a strong narrative, or white-label solutions aimed at value-conscious consumers?
- How can established players gain access to innovation in a deliberate, strategic way? Who are the best partners on this journey—startups and researchers that drive change, or investors that have an overview of the entire landscape?
- How should companies label and market alternative protein products—as plant based, vegan, climate friendly, or locally produced, or simply on the basis of taste, price, and convenience?



Accelerating Progress

Everyone has a stake in accelerating the protein transformation and, more broadly, the transition to a sustainable food system. Each stakeholder—whether a policymaker or regulator, a current value chain participant, an investor, a startup, or a consumer—has its own path to take. We see the need for concerted attention and action in five areas.

Support Farmers

Perhaps the least amount of attention to date has been devoted to the group that will feel the greatest impact of the shift to alternative proteins. Farmers are key enablers in the movement toward a more sustainable food system, they face some of the greatest risks, and—with the exception of large agribusiness companies—they have the fewest resources. As Lisa Sweet of the World Economic Forum says, “Most of the innovation has happened in the downstream value chain as opposed to promoting a truly sustainable transformation of farming practices. We need much better support for farmers making the shift to crops for human consumption.”

In the near term, farmers need to have clear economic incentives for fundamentally changing their business. “Sustainability must be sustainable for farmers as well,” says Johan de Schepper of Agrifirm. “We need to value the farmers and recognize their role,” adds Lisa Sweet. “The sooner we do this, the sooner the transformation will start.”

Eric Toone of Breakthrough Energy recommends looking to other sectors for models. “It is important for startups to engage farmers early in the process. They are part of the transition. One can think about paying them a premium (as for biofuels) for proteins grown for humans at scale.”

Governments can use their procurement muscle to build a market—and demand—for alternative protein crops. More supportive policies and regulations, such as reallocation of agricultural subsidies to support the transition to alternative proteins, are one possible avenue. Supporting farmers’ investments in growing new or different crops with longer-term contracts and price guarantees is another. Government-run institutions (such as schools and the military) and food programs can be big early customers for alternative proteins, which would give startups important sources of revenue and customer feedback and give farmers new sources of demand. This arrangement would also help build awareness of and acceptance for new products.

Ensure a Level Playing Field

“We need political willingness to repurpose subsidies to a resilient and planet-smart food system,” says Lisa Sweet. Policymakers and regulators have a big say in setting the rules and incentives that others play by. For example, right now, animal-cell-based meats are approved for sale only in Singapore. There is little incentive to invest in and develop these products without the prospect of a larger global market.

Government bodies and regulators can put alternative proteins on a more equal footing in multiple ways:

- Expedite regulatory reviews and approvals where possible, in line with national principles and consumer safety.
- Avoid labeling hang-ups. Word meaning and specificity are important, but consumers can also be relied on to exercise common sense. The inclusion of phrases such as “plant-based meat” or plant-based milk,” on product labels should not be treated as a justification for delaying or restricting availability.

- Ensure that subsidies for animal-based proteins and for alternative proteins are applied evenly or not at all.
- Require that sustainability metrics and measurement systems account for all environmental factors involved in food production, such as water consumption and emissions. We would all benefit from a more rigorous accounting framework that includes decarbonization measures, which most governments today do not require.
- Use dietary guidelines and campaigns to educate the public about the benefits of increased consumption of plant-based proteins.

Funding needs are often greater than venture capital (including corporate) funds can or are willing to underwrite, especially in capital-intensive areas such as building bioreactors. Governments should explore funding incentives or regulatory frameworks to boost alternative capital sources for infrastructure build-out. “I question whether venture capital alone can completely fund the cell-based industry, as the funding requirements to produce bioreactors and media at scale are so high,” says Kim Lovan of Black & Veatch, a US engineering and construction company. “Governments might need to jump in—with funding or by creating the right environment for funding.”

The war in Ukraine has underscored the vulnerability of global supply chains, and many policymakers are intently focused on their nation’s need to secure its food supply chains and become more independent. In doing so, they should recognize the contribution that alternative proteins can make. Alternative-protein supply chains are often shorter and more resilient than conventional animal protein production. “Dry textured products based on low-moisture extrusion can be produced with sustainable protein sources, or mechanically separated protein concentrates,” says Christoph Vogel of Bühler. “The dry textured products are shelf stable at ambient conditions for a long time and don’t need energy intensive cold storage before rehydration.” Some governments are already taking steps to invite infrastructure and technology players (such as companies building bioreactors for cell-based proteins) into their jurisdictions, pushing development of [local economic clusters](#) around alternative-protein capabilities.

Direct Capital at Transformative Ventures

Unfortunately, there is no free lunch—not even when it comes to food systems. Innovative companies will require significant amounts of capital as they develop protein sources, scale up bioprocesses, and bring ingredients to market. The food sector differs from more traditional venture capital investments, such as software and consumer services, in crucial ways. Upfront investments are often larger, and time horizons can be longer. But for the winners, the upside is also more stable, as they become integral parts of a new sustainable food system.

To identify the technologies and teams that have the highest long-term potential, investors must bring deep expertise to the table. Longer time horizons increase the need to provide post-investment value to portfolio companies to help realize returns—for example, by building networks and providing hands-on help with topics such as quantifying and communicating impact. Early-mover advantage is also critical. The technologies will continue to evolve and advance, and the business opportunities will become more complex. Barriers to entry can become formidable in a few years' time.

Investing in a sustainable food system is an effective way for corporations to expose themselves to innovation.

Venture capitalists aren't the only investors joining the game—and the newcomers are sorely needed. Rahul Ray of Tyson Ventures captures the conundrum succinctly: “A massive amount of capital is required to support startups to reach breakthroughs in technology and lower costs. Yet venture capital investors like fast returns. Success will take longer lead times and will require more capex than they are used to. Who will provide the capital? Corporations? The government?”

For corporations, investing in a sustainable food system is an effective way to expose themselves to innovation, and it can deliver much-needed environmental, social, and governance (ESG) benefits. Lisa Sweet puts it this way: “Lots of companies talk about their aspirations to reduce scope 3 emissions, but too few are showing responsibility and making the necessary investments.”

Different types of capital are needed for the sustainable food system to develop. Three of these are especially noteworthy:

- Creative structures from venture capitalists and corporate partnerships, such as prepaid offtakes, joint ventures, and different debt instruments to finance large capital expenditures
- Nondilutive research grants to support the earliest stages of R&D
- Infrastructure support from local governments

Finally, in addition to financial investments, corporations that know how to operate at scale can help the sector reach its true potential more quickly—and may be able to repurpose existing assets in the process. For their part, startups can try to work or partner more effectively with big companies, tapping into the latter's expertise in producing products at scale and leveraging their production capability.

Optimize Resources and Waste Recovery

The challenge here involves rethinking existing processes and practices. Waste has not systematically been considered as a relevant input factor for alternative proteins. Nevertheless, many food industry ingredients and by-products that usually go to waste could serve as a high-quality input, simultaneously reducing the overall costs of production and delivering environmental benefits. This idea has yet to be significantly leveraged. “In food production, waste reduction and valorization bear significant upside for transitioning toward a more sustainable food system,” says David Kestenbaum of ZX Ventures.

Key questions in the realm of waste recovery include the following:

- Which food industry inputs and by-products can be recovered and used in alternative protein production?
- Where can waste be avoided entirely or valorized to manufacture packaging and other nonfood items?
- How can food waste at the point of consumption be minimized?

Build Consumer Acceptance

Last but perhaps most important, consumer acceptance and use of alternative proteins must continue to rise. Progress in this area will determine the ultimate impact of alternative proteins.

We know that consumers have found some favorites among alternative proteins, but accelerating adoption depends on overcoming continuing inhibitors. Consumers are looking for better health and nutrition in food, and they are open to trying new options. To build more consistent consumption, the industry needs to push forward aggressively on improving taste, texture, price, and health. Companies also need to focus their marketing on factors that consumers value. “We need to keep one thing in mind: we do not eat proteins, we eat meals,” says Sir Charles Godfray of the University of Oxford. This means creating products and dishes that fit into people’s habits, not only to win over first movers, such as vegans and vegetarians, but to appeal to everyone looking for a tasty, healthy meal.

We also know that health and environmental concerns are strong motivations for greater consumption. The industry needs to make sure that consumers gain a better understanding of both sets of benefits.

Transparency and trust are additional key factors. “Plant-based proteins are easy to explain to the consumer—everyone gets it,” says Heinz Jürgen Kroner of Germany’s GEA Group. “Cell-based is a different story. Often, it seems to be too close to science fiction and a foreign topic for consumers. Creating transparency here is a major task for all of us.” Fabian Voichita of REWE Group puts it this way: “One of the main trends is traceability and transparency for ingredients. Creating end-to-end control up the value chain will be key to creating trust in the products and maintaining high quality.”

And price remains important, as our survey results show. “Price still drives the purchasing behavior of consumers,” says GEA’s Kroner. “We need to manage the shift to alternative proteins from a lifestyle product to an industrialized product at scale. Otherwise, a transformation toward a more sustainable food system will not be successful.” In this regard, as noted earlier, there may be opportunities for startups to partner with large companies or other startups in order to reach scale. New companies may not need to build their own production facility if a corporation has excess capacity.

Alternative proteins have already made their presence felt. Our consumer research suggests that the conditions are right for further gains as the next generation of healthy, tasty products hits the shelves, and our impact analysis shows that the protein transformation is one of the best tools available to combat the climate crisis. It’s still a heavy lift, but the faster the progress, the bigger the wins—financially for investors and sustainably for all of us.

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