

**ASSESSMENT OF THE MARKET POTENTIAL
FOR DEPLOYMENT OF BIO-SOLUTIONS
WITHIN THE U.S. FOOD AND
AGRICULTURE SECTORS**
THE DANISH MINISTRY OF FOREIGN AFFAIRS

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RAMBOLL

Bright ideas. Sustainable change.

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1. PREFACE

Collaboration and knowledge sharing are essential for the global food and agriculture sector's transition to more sustainable practises. Over the years, great advancements for the sector have transpired through knowledge sharing. In a Danish perspective, the tradition of sharing discoveries within biotechnology dates back to 1883 when the brewery Carlsberg purified brewer's yeast and published the results of their studies.

Today, the need for collaboration and innovative approaches is still of great importance, as the global food and agriculture sector faces the challenge of producing more food than ever while reducing climate impacts to a minimum. New intelligent solutions already see the day by applying advanced biotechnology to save resources throughout the value chain within food- and agricultural production. This new method is defined as bio-solutions.

Since Denmark has been at the forefront of biotechnology for decades and furthermore has many solution providers and universities strongly invested in the field, evident opportunities to export solutions and share knowledge occur.

To display the opportunities within bio-solutions, the most recent predictions for the market development within plant-based foods serves as a strong indicator. This report finds that the plant-based food market in the U.S. alone is expected to grow by approximately USD 47 billion between 2020 and 2035. An increase equivalent of an average yearly growth rate of 13 percent.

In the summer of 2021, the Danish government launched an action plan to strengthen green partnerships with the U.S. and share knowledge and experiences within climate and environment-related issues such as climate-smart agriculture and food production.

Therefore, it is at the core of the Trade Council in North America's work to support stakeholders pursuing activities in the U.S. and support the promotion of Denmark as a hub for bio-solutions abroad.

We look forward to facilitating and supporting partnerships that bring Danish experiences and solutions within bio-solutions across the Atlantic to bridge the gap between our two nations. We start by publishing this report providing a unique understanding of the rapidly growing market.

Mikkel Dam Schwartz

MINISTER COUNSELOR, FOOD, AGRICULTURE AND FISHERIES
Embassy of Denmark in the U.S.

2. EXECUTIVE SUMMARY

The U.S. is not surprisingly associated with a great potential for innovative technology, including bio-solutions. The large and growing population, becoming wealthier year by year, sets new requirements to how food is produced and what it contains driven by the increasing awareness on health and impact from climate change. The supportive regulatory conditions are another factor driving the market. Although the U.S. regulatory environment on biotech is complex and expensive to navigate in, it is generally easier and faster to introduce new biotech solutions than e.g. the EU. Furthermore, with its high interest in innovation and some of the world's leading research institutions, the U.S. is not only open to the new technology but also encourages its use across different sectors including food and agriculture. Lastly, the increasing pressure on the agricultural sector to increase the overall efficiency and cost optimization pushes the farmers and livestock owners to seek more innovative and high-tech solutions.

Both groups of bio-solutions in scope, i.e. enzymes for plant-based food proteins and alternative proteins via fermentation and digestive enzymes and probiotics for animal feed have a broad range of current and potential applications, some of which are still untapped.

Within the food track, using enzymes to improve the functionality of the plant-based meat and dairy are considered the most promising deployment areas, as the technology is believed to be capable to unlock the significant untapped potential within this market (currently constrained by the parity issues) already within the short to medium run. Although alternative proteins derived via fermentation are believed to be a ground-breaking solution on how to mimic animal-based proteins to perfection, the technology still has some significant milestones to reach before it can become fully competitive on price with e.g. the enzyme-technology.

Within the feed track, the highest potential is observed within digestive enzymes and probiotics to improve the efficiency of the cattle feed, as the deployment of this technology is assessed to be fairly behind to what is observed within e.g. the poultry industry. Driven by the growing pressure on cost and operations efficiency within this industry, and the increasing awareness of benefits connected to the use of enzymes and probiotics, the market is expected to start unlocking soon. Although the potential is assessed highest within the cattle industry, the other livestock groups, i.e. poultry and hogs are also considered attractive and high-growth markets, although the overall growth rates here are expected to be lower than in the cattle industry.

The most attractive states for the deployment of bio-solutions in scope include California, New York, Massachusetts, and Illinois for the food track and Midwest states, Oklahoma, Texas, and California for the feed track due to the overall supportive environment, comprising proximity to clients, knowledge centers and political encouragement of bio-solutions.

Based on the assessment of the market size and outlook for the potential client segments, and the geographical assessment, three different key opportunity spaces have been defined: 1) Deployment of enzymes as ingredients to plant-based meat in California, 2) Deployment of enzymes as ingredients to plant-based dairy in California, and 3) Deployment of enzymes to optimize feed efficiency for cattle/beef in California.

All of these opportunities are associated with potentially large and in most cases untapped market potential that can possibly be unlocked by bio-solutions. While obtaining alternative proteins directly via fermentation as it has significant potential in the longer run, the application of enzymes to improve the functionality of plant-based proteins is considered the most attractive technological option within the short to medium run.

Other states were considered to be relevant as well, e.g., New York, Illinois, Mid-West states, etc. However, the bio-solutions market is assessed to be particularly favorable in California. It is an attractive market with strong purchasing power, demand for innovative and green solutions, heavy R&D focus, and a strong presence of B2B companies that are relevant client segments for enzymes. It is also a large agricultural area focused on cattle holdings, meaning that the region is favorable for the enzyme producers targeting both the feed and the food markets. These advantageous conditions outweigh the somehow stricter regulation (mainly on the health claims) than is the case in some other states.

Although it might be in general considered easier to introduce new bio-solution to the U.S. than e.g. to the EU, it will in most cases require significant resources. New entrants will need promotion (both commercially and politically), distribution network, knowledge of the U.S. regulatory system, etc., which in most cases, will take a long time and be too expensive to build up on their own. While acquiring those capabilities is not an option for most of the bio-solution providers, collaboration and partnerships with larger and well-established market players (clients and/or competitors) will often be the best solution.

In addition to potential clients, competitors, and various regulatory agencies that the Danish solution providers need to approach and deal with when entering the U.S. market, there is a number of other various stakeholders that can potentially play an important role in enabling and enhancing the introduction of the above-mentioned technologies to the U.S. market. Those include supporting organizations, such as technology and knowledge hubs, research institutions, NGOs, etc., which can be helpful with regards to further innovation/technology sparring, promotion of bio-solutions in the U.S. market, lobbying for more supportive/favorable regulatory framework conditions at both the federal and state level and finding potential collaboration partners.

The key stakeholders for DMFA in their work with initiating a collaboration between the Danish bio-solution providers and the U.S. market include the Danish bio-solution providers and the various industry organizations both in the U.S. and in DK. These organizations should be involved in the initiative due to their close connection to the various market players (that can help in communicating and promoting the initiative) and their high interest in supporting the use of bio-solutions across various sectors. Other stakeholders, such as the regulatory bodies, various research institutions, knowledge hubs, etc. should also be informed about the initiative and potentially consulted on the relevant topics (e.g. participation in the webinars as speakers).

3. INTRODUCTION AND BACKGROUND

Ramboll has been commissioned by the Danish Ministry of Foreign Affairs (DMFA) to assess the market potential for bio-solutions within the U.S. food and agriculture sectors. The market study has been ordered in connection with DMFA's recently published action plan to strengthen sustainable export to the U.S. Danish companies offer a long list of climate-friendly and sustainable bio-solutions for agricultural and food production, which can help mitigate the current environmental challenges in the U.S.

This report aims to provide a basis for a better understanding of the U.S. market for bio-solutions within the food and agriculture sectors, including the key opportunities spaces. More specifically, the report provides an overview of the key market trends and drivers, the most attractive deployment areas, geographic relevance, and the key stakeholders (including potential collaboration partners).

Bio-solutions is a comprehensive category, containing multiple technologies and application areas, even if only considering the food and agriculture sectors¹. The scope of this report has been narrowed to focus on three bio-solutions that are considered representative for the Danish bio-solution sector (with a potentially broad range of providers), with an expected highly positive impact on the environment (and the climate), associated with high market potential, and with a high technological readiness level (fully commercialized or potentially close to industrial commercialization). These bio-solutions are:

- Within food: [Enzymes for plant-based proteins](#) (to improve the functionality of the plant proteins, e.g. taste or texture) and [alternative proteins derived directly via fermentation](#).
- Within agriculture: [Digestive enzymes and probiotics for feed](#) (digestive enzymes are used to improve feed conversion ratio, while probiotics help balance the environment of the gut so it can stay healthy and work efficiently).

Although the analysis focuses mainly on these two solutions, many of the key conclusions in the report are expected to apply to a broader range of Danish bio-solutions.

The report is prepared in several sections, each focused on answering a key question relevant to understanding the market potential for bio-solutions in the U.S.:

- [Section 3](#) presents a high-level overview of megatrends and market drivers with a direct impact on the development of the U.S. bio-solution market.
- [Section 4](#) provides an overview of the key deployment areas for the bio-solutions in scope, including the typical client types and an evaluation of the competitive landscape.
- [Section 5](#) gives insights on the key opportunity spaces based on an analysis of the indicative market size and potential for the different application areas, combined with the geographical (state-level) relevance.
- [Section 6](#) provides an overview of the key stakeholders within identified opportunity spaces.
- [Section 7](#) presents Ramboll's recommendations to the Danish bio-solution providers considering market entry and to the DMFA on how to enhance collaboration between the Danish companies and the U.S. market.

¹ Key bio-solutions offered by the Danish companies (identified based on dektop research and interviews with market experts):

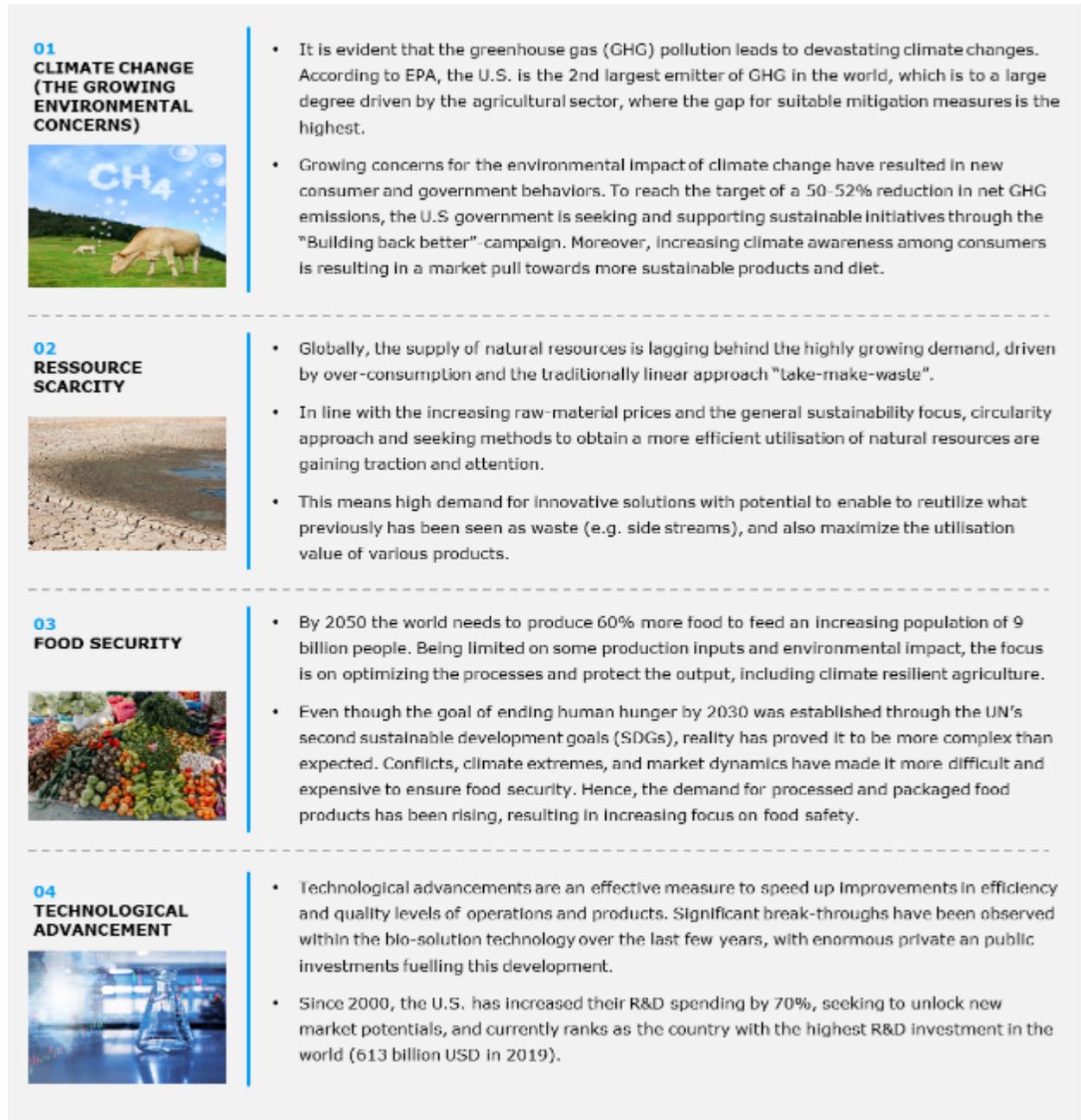
- Bio-protection: Natural microbial cultures and enzymes are added to foods to extend their shelf life.
- Enzymes for plant-based proteins: Improve functionality of plant proteins, e.g. taste, texture, etc.
- Alternative proteins via fermentation: Production of (specific) food or feed proteins directly via fermentation.
- Digestive enzymes and probiotics for feed: Digestive enzymes are used to improve feed conversion ratio, while probiotics help balance the environment of the gut so it can stay healthy and work efficiently.
- Microbial alternatives to fertilizer: Use of microorganisms that can release nitrogen, thereby replacing the need for fertilizers.
- Bio-pesticides: Use of microorganisms to control for many different kinds of pests. Bio-protection for feed.
- Methane-free cattle production: Use of bacteria to change the bacterial composition in the cow's rumen and thereby reduce the cows' methane emissions.
- Enzymes for bio-gas production: Enzymatic pre-treatment of biomass in biogas production (via anaerobic digestion).

4. MARKET TRENDS AND DRIVERS

4.1 Megatrends

Megatrends are global, long-term change developments that impact business, economy, industries, societies, and individuals. They are typically a combination of multiple trends, phenomena, and issues that are intertwined with each other. Ramboll has identified four closely interlinked megatrends which are expected to impact the U.S. bio-solutions markets (Figure 1).

Figure 1: Key megatrends impacting the market for bio-solutions



4.2 Market drivers

While the megatrends described in the previous section are measurable, long-term developments with a positive impact on the bio-solution markets, the focus of this section is to assess the key underlying causes of change, i.e. the [key drivers for deployment of bio-solutions in the US](#). The five drivers identified throughout this include:

- The increasing population, in confluence with the inflating disposable incomes in the U.S:** The U.S. ranks as the world's 2nd largest agricultural sector with a 16% share of the total global methane emission. While the population is constantly growing, the demand for food and protein is increasing at an even higher rate, driven by the increasing disposable income levels (a "typical" buyer of alternative proteins is 18-64 years old, with an income above 50,000 USD/year and higher education). This means that the U.S. agriculture sector will need to supply food for the growing population, while at the same time addressing the climate crisis and how to meet international carbon neutrality targets. Bio-solutions are a potential and promising measure to achieve that.
- Client awareness and growing demand for "clean label", "all-natural", "vegetarian", and "free-from" food:** An increasing health awareness resulting in a desire to consume "free-from" and more natural, clean labeled products, and the growing demand for non-animal food due to ideological and environmental concerns are among the key underlying drivers. To achieve their full potential, plant-based food products need to overcome such challenges as parity on taste, texture, and price. Some of these issues are expected to be solved by evolving technology and innovation-driven by large investments in this sector. However, the perception of modified food as unhealthy and unappealing is a huge challenge that can be difficult to handle, even though the food that only contains gene-modified ingredients (e.g., enzymes) is not labeled GMO in the U.S. (as opposite in e.g., EU). Despite growing popularity, alternative proteins are not expected to completely replace animal-based proteins in the short and medium-term (and possibly not even in the long run), but rather be a valuable supplement to the animal-based diet.
- Supportive regulatory conditions encouraging biotech:** The U.S. is often the first place to introduce new biotech technology, as the regulatory requirements are in many cases less strict than in e.g. Europe. Moreover, the U.S. has started modernizing the regulation of bio-solutions to make it more convenient and further encourage technological development. On the contrary, the U.S. regulatory landscape on biotech can be difficult to navigate at the moment – interfaces between various federal regulators (Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), and the U.S. Department of Agriculture (USDA)) are not always clear. Furthermore, the key regulating statute within the area (Federal Food, Drug, and Cosmetic Act or "FFDCA") is being updated quite often making the regulatory understanding even more complex. While the safety regulations are federal, various states have their measures on other areas – e.g. labeling (what can be labeled as "meat" and what cannot), and economic incentives to attract and encourage biotech. This is often driven by local politics, and it is also subject to constant change due to excessive lobbying. Thus, despite favorable conditions for introducing new technologies, establishing in the U.S. can require a lot of resources and/or collaborations with market players having the right resources.
- Focus on the cost optimization in the agricultural sector:** Feed typically accounts for up to 70% of the overall cost of feedstock operation in the U.S. Although large efficient improvements have been achieved through contemporary farming practices, bio-solutions have the potential to enable additional cost reductions by improving the feed conversion ratio. At the same time, this would have a positive impact on the environment, due to lower pressure on resources due to lower demand and better utilization of waste streams.
- Increased adoption of advanced technology:** The U.S. ranks high across countries when it comes to the adoption of new technologies. This also applies to biotech incl. the enzyme technologies across different end-applications and is among others seen by an increasing number of scientific publications within this area.

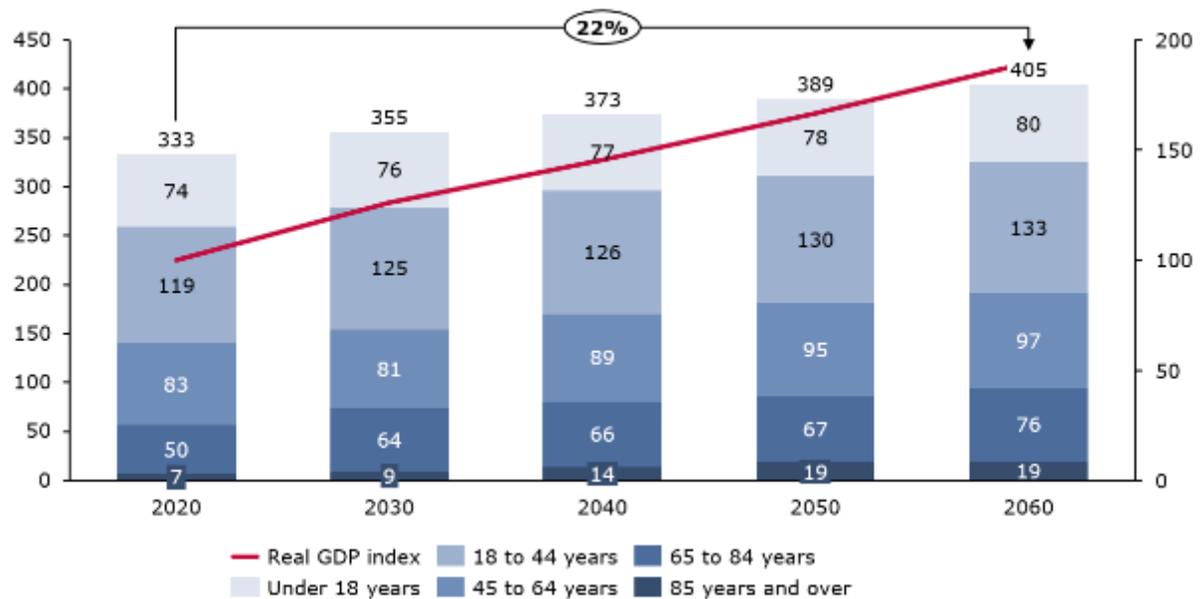
Each of the drivers is described in detail below.

4.2.1 Increasing population, in confluence with the inflating disposable incomes

The U.S. ranks as the world’s 2nd largest agricultural sector with a 16% share of the total global methane emission². Moreover, feed production and processing account for 45% of the total GHG emissions within the U.S. agricultural sector³. Thus, the U.S. agricultural sector faces an enormous challenge: it will need to supply food for the growing population, while at the same time addressing the climate crisis and how to meet international carbon neutrality targets.

The demand for food and protein in the U.S. has lately been increasing at an even higher rate than the population growth⁴. In 2020, the U.S. had a population of 333 million people, and it is forecasted to increase to 405 million in 2060, equivalent to an increase of 22%. At the same time, the U.S. real GDP is expected to increase by ~90% from 2020 to 2060 resulting in an increasing GDP per capita⁵. Research shows that there is a proven positive relationship between per capita income and the demand for food sources high in proteins⁶.

Figure 2: Total recorded and forecasted population (millions) and GDP index in the U.S., 2020-2060



Sources: OECD data & U.S. Census Bureau

Increasing income levels do not only impact the demand for proteins, but also alternative proteins. According to behavioral research, specific demographics characterizing “typical” consumers of alternative proteins include age (people within the age bracket of 18-54 years), income level (greater than 50,000 USD), and education level (a college or graduate degree)⁷. As both the U.S. population within this age bracket and their disposable incomes are increasing, the demand for alternative proteins is expected to increase accordingly.

As implied by statistics presented in Table 1 below, people older than 65 currently have the lowest spending levels on alternative proteins, and thus the lowest likelihood of purchasing food based on alternative proteins. However, according to the research, 40% of all meals in care facilities are

² International Energy Agency (2021): <https://www.iea.org/articles/methane-tracker-database> ; Dutta, S. (2020)

³ Grossi, G., et al. (2018): <https://academic.oup.com/af/article/9/1/69/5173494>

⁴ Calicioglu, O., et al. (2018): <https://www.mdpi.com/2071-1050/11/1/222/pdf>

⁵ OECD (2022), Real GDP long-term forecast (indicator)

⁶ Andreoli, V., et al. (2021)

⁷ Good Food Institute (2020)

prepared as special diets, which primarily includes texture modification⁸. As the bio-solution technology within the area is evolving the elderly segment, it could become a market driver.

Table 1: Consumer demographics

	Cohort	Buyer index	Dollar index
HH age	HH age 18-34	111	118
	HH age 35-44	111	122
	HH age 45-54	106	116
	HH age 55-64	96	90
	HH age 65+	83	70
HH educat	HH graduated high school or less	81	64
	HH some college	97	91
	HH graduated college	108	116
	HH post-graduate school	115	133
Ethnici ty	White	96	95
	Asian	132	112
	African American	105	117
	Another race	105	112
Income	HH income under \$20k	81	71
	HH income \$20k-\$24.9k	79	59
	HH income \$25k-\$34.9k	88	77
	HH income \$35k-\$44.9k	94	89
	HH income \$45k-\$49.9k	92	93
	HH income \$50k-\$59.9k	101	100
	HH income \$60k-\$69.9k	103	101
	HH income \$70k-\$99.9k	106	103
	HH Income \$100k+	115	132
Kid	HH with children	109	115
	HH without children	96	93

Note: The table shows the buyer index (i.e., the level of interaction with multiple different alternative protein products) and dollar index (i.e., the dollar amount spent on alternative protein products) for each consumer cohort. The purpose of the table is to uncover which consumer cohorts are the typical purchaser of alternative protein products.

Source: Good Food Institute (2020)

4.2.2 Client awareness

In most developed countries, animal proteins have been the main source of proteins during the last few decades. Although the overall demand for proteins is increasing, the growth rate of animal proteins is expected to decline by approximately 50% in the coming years⁹, due to changing consumer preferences towards alternative protein sources. This is mainly driven by two significant trends driving the increase in U.S. sales of plant-based proteins by 45% from between 2019 and 2020, making the U.S. account for 25% of the global sales of plant-based proteins¹⁰:

- Increasing health awareness and the desire to consume “free-from” and more natural, clean labeled products, and
- The growing demand for food that does not rely on animal protein, due to ideological and environmental concerns.

According to a survey conducted by Mattson in 2020, 80% of U.S. consumers believe that these trends are significant and expect them to be long-lasting.

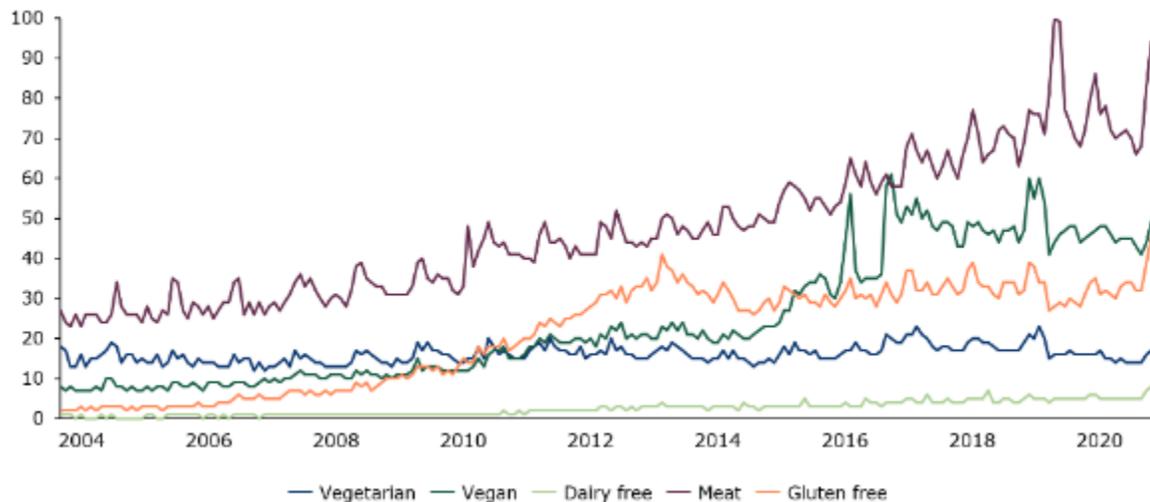
⁸ International Union of Food Science and Technology (2014): <http://www.iufost.org/iufostftp/IUF.SIB.Meeting%20the%20Food%20Needs%20of%20the%20Ageing%20Population.pdf>

⁹ Bashi, Z., et al. (2019): <https://www.mckinsey.com/industries/agriculture/our-insights/alternative-proteins-the-race-for-market-share-is-on>

¹⁰ GFI (2020)

Analyzing search queries of U.S. consumers can indicate how the specific interest in food preferences has evolved over the last 15 years. Even though meat has been the most searched term, the search term “vegan ” started to gain popularity since 2004 and became even more popular than “vegetarian”, “dairy- and gluten-free” (see figure 3) starting in 2016. The increasing interest in veganism indicates an increasing demand for clean and environment-friendly products among the U.S. population. This is supported by the U.S. meat consumption being the world’s 3rd highest with 315.5 grams consumed daily per capita¹¹. However, consumption per capita has only risen 4% from 2000 to 2021¹². In contrast, the number of vegans in the U.S. has increased by 500%, as 1% of the population was vegan in 2014 increasing to 6% of the population in 2017¹³.

Figure 3: Search queries of U.S. consumers normalized to the highest point, 2004-2021



Source: Google Trends

As described in the previous section, research established a positive relationship between wealth and healthy food choices. Moreover, several consumer studies (e.g. Mattson (2020) and McKinsey dairy survey (2018)), reveal important findings of consumer motivations to purchase alternative proteins:

- Health reasons:** Consistently, they find that health is the primary reason for consuming alternative proteins. More specifically, in 2018, 82% of the respondents have viewed alternative proteins as healthy and being the key reason for purchasing them. However, the same study showed, that only 74% of the respondents have viewed animal proteins as the healthier choice¹⁴. The main reason for these mixed signals is believed to be poor communication of the health claims for alternative proteins. For example, both Whole Foods (a natural/organic-focused supermarket) and Chipolte (restaurant chain) have criticized Beyond Meat’s products for being highly processed. Thus, clearer and prove-based communication is required to secure growth in the alternative proteins market.
- Climate and environment:** According to Mattson (2020), climate and environmental benefits motivate ~50% of U.S. consumers to buy alternative proteins instead of animal-based. Interestingly, the same report found that the share of consumers trying to eat more alternative proteins due to health reasons decreased by 17%-point between 2017 and 2020 (to 65%). This suggests that buying behavior is increasingly being driven by environmental concerns and sustainability awareness.

¹¹ FAO (2017):

¹² USDA (2021)

¹³ GlobalData (2017)

¹⁴ McKinsey Survey (2018)

Currently, the U.S. population consists of 6% vegan/vegetarian, 10% flexitarian, and 84% meat-eaters. More than 50% of consumers within the latter two groups are continuously trying to reduce their meat consumption¹⁵. A more significant shift in distribution is expected going forward, as the youths are more likely to shift the proteins source (38% of generation Z is willing to change protein sources to plant-based, compared to only 20% of the Boomer generation¹⁶). However, full elimination of animal proteins is not likely, as the U.S. population consumes approximately twice the amount of animal protein compared to the global average¹⁷. Thus, plant-based proteins are by many experts expected to take on a role as a healthy supplement to the U.S. food habits, rather than a full replacement for animal proteins.

Despite the rapidly growing demand for alternative proteins, some significant challenges need to be addressed and overcome before alternative proteins can become fully competitive with animal-based proteins. Approximately 27% of U.S. consumers report that they do not like the taste of alternative proteins and 20% do not like the texture¹⁸, which has been recently manifested by the case of Beyond Meat. On the first trading day of its IPO, the stock price soared an incredible 163%, but the company has since had troubles living up to its high growth expectations, which is believed to be primarily caused by product reception issues. To become competitive, alternative proteins will therefore need to reach parity with animal proteins within two key areas:

- **Taste and texture:** The taste and texture of alternative proteins must emulate familiar flavors in the context of the food. Thus, alternative proteins used as a substitute to meat, seafood, dairy, and eggs must taste and smell like the replaced protein.
- **Visual expression:** In addition to the taste, alternative proteins need to visually resemble the original animal proteins. It is currently difficult to reach parity on this under the regulation of color additives. Moreover, the appearance includes imitating the fiber structure, which is the most advanced area and closest to parity. Primarily, this is driven by fermentation-based products, where experts claim that they are indistinguishable from animal-based products.
- **Price parity:** At present, alternative proteins are not doing well on price competitiveness compared with animal proteins due to the high cost of production. According to Piper, the average price in 2019 for plant-based meat substitutes sold in a U.S. supermarket was ~10 USD/pound. In comparison, the average price for beef was ~5 USD/pound, while chicken proteins were even cheaper, at ~2 USD/pound¹⁹. If the buying behavior of consumers is to change towards repeated purchases of alternative proteins, the cost must at least match that of animal-based proteins. A large share of the U.S. consumers is highly price-sensitive, making the huge supermarket chains, such as Walmart, base their strategy on low-cost products. Hence, it is often not feasible for them to adopt new technology that increases production costs, and in turn, also profit margins.

This being said, technology for the production of alternative proteins is today at still a relatively early maturity stage (some more mature than others) and quickly developing. Consequently, some of the challenges are expected soon to be partly or fully solved by innovations fueled by enormous investments in the alternative protein industry. In 2020, the industry secured 2.2 billion USD, which is more than in any other single year in the industry's history (and double of what has been invested within the industry since 1980). Moreover, the number of new investors within the alternative protein industry has increased by 44% between 2019 and 2020²⁰.

However, another important challenge that can be more difficult to address, is the public perception of the technologies projected to drive the growth of alternative proteins. Alternative protein consumption is expected to grow in three waves: plant-based, microorganism-based, and animal-cell-based proteins. However, many consumers have difficulties accepting animal-cell-based and genetically modified organism (GMO) food products due to poor communication of what these

¹⁵ McCracken, C. (2019)

¹⁶ McCracken, C. (2019); Baby Boomers are people born between 1946 and 1965 while Gen Z are those born from the mid-to-late 1900 and early 2010, so typically in the year 2020.

¹⁷ Dumas, P., et al (2016)

¹⁸ Good Food Institute (2020)

¹⁹ Piper, K. (2020)

²⁰ Good Food Institute (2020)

terms mean, and what are the associated risks and benefits (and what are not). The Power of Meat 2019 study published by The Food Industry Association showed that 71% of U.S. consumers did not find it appealing to buy food products based on animal-cell proteins or GMOs²¹, although another study suggests that there is a knowledge gap of GMOs resulting in misdirected consumers. If the consumers instead were asked if they were interested in buying products that are engineered to be more sustainable, approximately 70-80% would be willing to buy them²². Even though most of the consumers do not understand the GMO technology, negative focus towards it is driven by some large organizations through pledges and label certifications. For example, Danone has pledged to significantly transform its dairy products into more non-GMO and use non-government and more strict labeling as evidence²³. Given the current regulations in the US, products where ingredients that come from modified sources (e.g. bacteria modified to only produce a certain type of enzymes) are used only to improve the product functionality and to not have a function in the end product, will not be viewed as a GMO, but they can still face negative media attention initiated and encouraged by opponents (e.g. activist groups or conventional food competitors that try to protect their market against new entrants). Therefore, as presented later in this report, it will be important for the new entrants to have the resources to navigate within the regulatory landscape, and also a proper data basis to debunk a myth. It will also be important to consider collaborations with other large companies and interest organizations to work together towards marketing and promoting bio-solutions-based food as a healthy and environment-friendly alternative. As elaborated in the following sections, collaborations can also be entered with competitors, including the conventional food companies, by branding the products as complementary and not a substitute to the conventional products. Many large meat and dairy producers are interested in expanding their portfolio to also include alternative proteins.

4.2.3 Regulatory frameworks

United States is often the first place to introduce new biotech technology, as the U.S. regulation is on some areas related to food and feed ingredients deemed less strict than e.g. in the EU. The Food and Drug Administration (FDA) has historically been developed as a consumer protection agency, in contrast to the European Commission and the resulting regulations, which were established due to a need of harmonizing inter-state interests while preserving national autonomy. Thus, the FDA has the advantages of a centralized set of common rules, whereas the European Union regulates the approvals through a network of centralized and decentralized agencies throughout its member states²⁴. This results in a more complex and lengthy approval process than in the U.S. (approval process for new biotechnology is assessed to be significantly faster in the U.S. than in the EU – Interviews suggest that it typically takes 5-8 years in the EU, compared to 2-4 years in the U.S.)

However, despite more pragmatic regulatory conditions, the U.S. regulations on food and feed ingredients are still very complex and can be difficult to navigate in, as the interfaces between various federal regulators are not always clear. Furthermore, the key regulating statute within the area (Federal Food, Drug, and Cosmetic Act or “FFDCA”) is subject to regular updates, making the regulatory understanding even more complex to navigate in.

While the safety regulations are set on the federal level, various states have their measures on other areas relevant for bio-solutions, for example, labeling (what can be labeled as “meat” and what cannot), and economic incentives to attract and encourage biotechnology. This is often driven by local politics and is also subject to regular changes.

Thus, despite favorable conditions for introducing new technologies, establishing operations in the U.S. requires a profound knowledge of the federal and state regulations, and in many cases significant resources. Therefore, some companies choose to collaborate with larger players to get help within the regulatory sphere.

²¹ FMI (2019)

²² Chr. Hansen

²³ The Organic & Non-GMO Report (2017)

²⁴ Norman, G. (2016)

The regulatory landscape and its impact on the market for bio-solutions (including key opportunities and challenges) are described below, both at the federal and regional levels.

Federal level

At the U.S. federal level, bio-solutions are primarily regulated by three key agencies: the FDA, the U.S. Environmental Protection Agency (EPA), and the U.S. Department of Agriculture (USDA). However, only two regulatory agencies are relevant for food and feed additives: the FDA (which is the main agency body within this area), and the USDA (supporting FDA in certain areas such as labeling and animal protein control).

All introductions of new feed or food ingredients have to be approved by the FDA under the FFDCA. This act establishes a national framework for the safety- and nutritional management of bio-solutions within the food and feed including harmful ingredients, color additives, and labeling. Since its enactment in 1938, there have been at least 35 amendments to the act making the regulation more complex. Generally, the FFDCA requires that a bio-solution producer can demonstrate how the food additives i.e., enzymes, etc., with reasonable certainty will not result in any harm for the intended use. In comparison, the European Food Safety Authority has more strict requirements as they require with certainty that *"it does not pose a health concern to the consumer; there is a technological need for its use, and its use does not mislead consumers"*²⁵.

The process of demonstrating this varies depending on the characteristics of the additive. In the food additive provisions of section 409 of the FFDCA, it is required premarket approval for any food additive, regardless of the technique used. An exempt from this regulation are food additives that are generally recognized as safe (GRAS). In the U.S., cultured milk and egg proteins are likely to be defined as GRAS which probably will be valid for the plant-based categories as well²⁶. This could potentially drive the market for plant-based dairy and eggs.

The FFDCA also regulates the food coloring additives, where nine colors so far are certified. However, color additives that are derived from natural sources i.e., vegetables and minerals, are exempt from this regulation. Having color regulations could challenge the attractiveness of plant-based proteins compared to animal proteins as the appearance is important to the consumers.

The USDA sub-division "Food Safety and Inspection Service" is concerned about supplying safe, wholesome, and correctly labeled meat to the U.S. population. In 2016, Congress passed the [National Bioengineered Food Disclosures Standard Law](#), which gives USDA the authority to regulate the disclosures for bioengineered foods and ingredients. The statute could potentially drive the market of the bio-solutions within the scope as a more strict or liberal change will impact them. *The National Bioengineered Food Disclosures Standard Law* requires mandatory labeling for bioengineered food and ingredients. Based on the U.S. definitions of bioengineered food and ingredients (GMO), it is unlikely that cultured proteins will be considered as "bioengineered" foods or ingredients under this regulation. However, depending on the status of the inputs used to produce these proteins, they might be considered to be derived from bioengineering. As this law recently went into effect, there is still uncertainty whether the bio-solutions within scope have to comply with this law. This law could potentially benefit bio-solutions exempt from it, as consumers become aware of the content of the food and feed they buy. However, multiple non-government organizations in the U.S. have established label certifications, which have more strict requirements than government regulation. Especially within the organic and GMO areas, these certification labels are apparent.

In general, Ramboll has identified three federal regulatory trends that would impact the deployment significantly of bio-solutions in the U.S. over the coming years:

- The U.S. regulators are looking into a [stricter definition of food and feed safety](#) which in the future might lead to more food additives being characterized as harmful. Potentially, this gives more market space to the bio-solutions as a product derived, this way is in many cases considered natural and less harmful than the chemical alternatives. However, this characteristic must be proven scientifically, and with stricter regulation, it could potentially be more expensive and increase the duration of the process.

²⁵ EFSA: Food enzymes

²⁶ PATH (2019): Cultured Proteins: An Analysis of the Policy and Regulatory Environment in Selected Geographies

- Today, the FFDCAs sets a specific regulatory framework for chemical substances within the food and feed segment, as the chemical technologies have been practiced for a long time making the regulation more mature. As no similar framework currently exists for bio-solutions, they need to fit into regulations for chemical substances, even though it is not optimal in most cases. This has put high pressure on the government to modernize the regulatory system for biotechnology. In 2015, the three regulatory agency bodies decided to prepare a new regulatory pathway for biotechnology, which could ensure an easier and more efficient process for approval of bio-solutions within the food and feed sectors. Moreover, the FDA is specifically committed to supporting the bio-solutions for plants and animals: *"The agency will use a robust public communication strategy, with direct support and involvement from the FDA's Commissioner and senior agency leaders, to engage with our stakeholders on innovations in plant and animal biotechnology"*²⁷. In 2017, a task force was established to identify legislative, regulatory, and policy changes. To our knowledge, the implementation of the new regulatory pathway for biotechnology is currently still undergoing.

As the regulation on food and feed safety is becoming stricter in the confluence with a new regulatory pathway specifically for biotechnology, the regulatory system in the U.S. has the potential to become a significant market driver of bio-solutions. However, the complexity of the regulation and an entirely new regulatory system makes it difficult to navigate. Thus, the U.S. regulatory landscape is potentially a challenge for the bio-solutions companies operating within or entering the U.S. market, as it means the companies need to either spend significant resources on the legal topics or partner up with other companies that have the necessary staff and experience. This can potentially have a negative impact on the speed of market development.

Policy and incentives at the federal level

Bio-solutions have the potential to help solve both the environmental impact and the food security challenges by optimizing livestock feed digestion which results in less feed needed. The need for new measures within these areas is also anticipated by the U.S. government. To help the farmers who are often unaware of their impact, the U.S. government provides incentives through the Sustainable Agricultural Systems (SAS) program, making it easier to adopt new technologies to accommodate President Biden's methane reduction policy²⁸.

In 2019, the National Institute of Food and Agriculture, a sub-division of USDA, outlined a new policy initiative under the (SAS) program which emphasized increasing federal focus on the sustainable supply of abundant, affordable, safe, nutritious, and accessible food and other agricultural products, while enhancing economic opportunities and improving the long-term health and well-being of all Americans. Overall, this plan reinforced all the megatrends discussed in section 2.1 and signaled an increased federal focus on achieving increased sustainable production. The majority of policy objectives are educational, voluntary, and fund-based. However, with limited funding resources and a lack of legislative force, these policies are not fully utilized.

The SAS program is defined at the federal level; however, it is being executed on the state level resulting in the lack of legislative force. State political officials often have different agendas when it comes to the use of enzymes. Especially, the agricultural sector is a sensitive area for politicians as the sector in 2020 employed ~10% of the total U.S. employment²⁹. Agricultural representatives seek optimization of processes; however, they also see the threat from alternative proteins. As a consequence, the transition towards more sustainable and cost-effective bio-solutions is happening at a slower rate.

State-by-State level

Although the regulation on the safety and health of food and feed is happening at the federal level through the FDA and USDA, each state can show more encouragement towards bio-solutions than the others. As long as each state respects the Supremacy Clause (stating that federal laws govern state laws), they can pass a policy that only applies to the residents and business entities who are located in the respective state. For example, this is expressed by economic incentives (e.g., R&D

²⁷ FDA (2018): Plant and Animal Biotechnology Innovation Action Plan

²⁸ The White House (2021)

²⁹ USDA (2021): Ag and Food Sectors and the Economy

tax credits and tax credits to investors) and direct investments/partnerships (e.g., private/public investments and partnerships), which potentially drive the market for bio-solutions.

In the U.S., incentives, and laws are primarily driven by lobbying from industry associations and stakeholders. Just in 2020, these organizations have spent over 3.5 billion USD on federal lobbying and campaign contributions³⁰. According to Allison and Harkins, companies lobbying realize huge gains, “on average, for every dollar spent on influencing politics, the nation’s most politically active corporations received 760 USD from the government”³¹.

The industry association for farmers/animal protein and alternative proteins might in some areas have conflicting interests, as they are trying to secure market space and workplaces. Labeling is a regulation area of considerable lobbying by both the animal protein industry groups (e.g., the National Cattlemen’s Beef Association) and alternative protein industry groups (e.g., the Plant-Based Foods Association). The National Cattlemen’s Beef Association placed preventing ‘false and misleading’ marketing of plant-based products high on its 2019 policy priorities. The six states Texas, Missouri, Mississippi, Louisiana, Arkansas, and South Dakota have passed laws restricting the use of ‘meat terms’ to describe plant-based alternative products³². However, the Plant-Based Foods Association has in collaboration with other organizations fought similar laws in other states, and they have won in Virginia and California. Moreover, they have pending cases in some of the states above³³.

Biotechnology industry associations have lobbied for better conditions in the different states for biotechnology companies. They have secured better funding in the early stages of the R&D process, provided biotechnology investors better tax credits, and tax credits to biotechnology companies. The political incentives for each state can be found in Tables 7-12.

4.2.4 Need for cost optimization

The expense of feeding livestock and poultry typically accounts for up to 70% of the overall cost of operating a livestock and poultry operation³⁴. Farmers have in decades strived to optimize their operations and to reduce this cost. Although contemporary farmers have made incredible progress in the overall efficiency improvements, the technological advancement within the digestive enzymes and probiotics can potentially enable them to improve further, while at the same time having a positive impact on the environment and animal welfare. If the enzymes are proved to be able to bring the total cost of production down significantly, they have the potential to quickly become industry standard³⁵.

This is especially relevant considering the rising costs of natural resources. The U.S. is the 6th largest consumer of natural resources per capita globally (e.g., crops, livestock, etc.)³⁶. If all humanity had similar consumption to the U.S. in 2020, we would have depleted the natural resources with 400% more than what the biosphere can regenerate³⁷. In the last two years, the price of the key feed inputs, i.e. soy and corn has increased by 43% and 57%, respectively³⁸, driven by the increasing demand not matching the supply. Bio-solutions have the potential to help the farmers introduce local and cheaper nutrition sources to the feed-mix, by improving the digestibility levels of e.g., waste streams. This could benefit both the economy and the environment.

Previously, antibiotics have been used in livestock both for preventing bacterial diseases in herds and as growth promoters. However, the latter has been made illegal by the FDA in 2017, due to a

³⁰ Statista: <https://www.statista.com/statistics/257337/total-lobbying-spending-in-the-us/>

³¹ Allison, B. & Harkins, S. (2014): <https://sunlightfoundation.com/2014/11/17/fixing-fortunes-biggest-corporate-political-interests-spend-billions-get-trillions/>

³² Ikigai Law (2021)

³³ Good Food Institute (2020)

³⁴ Alqaisi, O., et al. (2017): “Time series livestock diet optimization: cost-effective broiler feed substitution using the commodity price spread approach”

³⁵ Witte, B., et. al (2021): <https://web-assets.bcg.com/a0/28/4295860343c6a2a5b9f4e3436114/bcg-food-for-thought-the-protein-transformation-mar-2021.pdf>

³⁶ Earth overshoot day: <https://www.overshootday.org/newsroom/infographics/>

³⁷ Earth overshoot day: <https://www.overshootday.org/newsroom/infographics/>

³⁸ BusinessInsider, Markets

push from the World Health Organization to prevent the emergence of antibiotic resistance³⁹. Moreover, the controversies and experts' concerns about the negative impact on the entire food chain remain. Consequently, the sales of medically important antibiotics have declined by 36% since 2015⁴⁰. This has forced farmers to search for alternative ways to promote growth healthily and sustainably making market space for bio-solutions. The farmers have been reflecting acceptance of feed enzymes and probiotics since the recent legislative development⁴¹. Rising acceptance among farmers is a key driver for the market of digestive enzymes and probiotics for animal feed.

4.2.5 Increased adoption of advanced technology

Innovation is an important parameter that tracks a country's advancement in developing and using new technologies. In 2021, The U.S. ranked 3rd on the Global Innovation Index, only surpassed by Switzerland and Sweden. The ranking is based on 80 factors grouped in innovation inputs and outputs making it a beneficial indicator of the willingness to adopt new advanced technologies. Thus, by ranking the third best, the U.S. emerge as a country of particular interest for providers of advanced technologies.

Environmental science is the most significant research field in the U.S. by the number of publications in 2020. The number of publications has doubled during the last couple of years, indicating high activity levels and interest within this field⁴². Environmental technology advancements (of which bio-solutions are a sub-sector) have been a particularly popular topic.

Moreover, the U.S. has historically accounted for approximately 62% of all biotechnological patents granted globally⁴³. Thus, the U.S. is not only interesting as they ranked 3rd on the Global Innovation Index, but they are also interested in this particular setting, as they are showing an interest in biotechnological solutions, specifically. Consequently, the generally high interest in and adaptation rate of biotechnological solutions across different end-applications is expected to be among the key factors driving the bio-solution market.

³⁹ University of Minnesota (2020): <https://www.cidrap.umn.edu/news-perspective/2020/12/fda-reports-another-rise-antibiotic-sales-livestock>

⁴⁰ University of Minnesota (2020): <https://www.cidrap.umn.edu/news-perspective/2020/12/fda-reports-another-rise-antibiotic-sales-livestock>

⁴¹ Future market insights

⁴² Web of Sciences (Clarivate)

⁴³ U.S. Patent and Trademark Office

5. KEY DEPLOYMENT AREAS

Both groups of bio-solutions in scope, i.e., *enzymes for plant proteins and alternative proteins via fermentation* and *digestive enzymes and probiotics for animal feed* have a broad range of current and potential applications, some of which are still untapped.

Today, *enzymes for plant proteins and alternative proteins via fermentation* are mostly used as an aid in the production of food, i.e., in the process but without having a function in the end product.

While enzymes are used across multiple processing stages to improve the functionality and nutritional values of plant-based proteins (with new application areas being constantly identified and tested), producing alternative proteins via fermentation (e.g. precision fermentation) is a newer and less mature technology and therefore still less widespread. However, it is associated with a considerable potential across industries currently dominated by animal proteins such as dairy, meat, and eggs, since alternative proteins produced via that route are quite similar to animals' proteins and can potentially solve the parity problems related to taste and texture.

Typical customer groups include traditional food production giants, producers of plant-based alternatives, and distributors, all potentially being both clients and competitors. While distributors would be the most relevant for less complex products, food producers (both traditional and plant-based) are also relevant for the more innovative solutions. While the large food giants and the more traditional producers of plant-based food (using enzymes to improve quality) are the most obvious client groups at the moment, the untapped potential is assessed within the current generation of innovative plant-protein products, that still use synthetic/unnatural additives to improve the functionality of their products (could be replaced with nature-based enzymes).

Digestive enzymes and probiotics for animal feed are today being used by many farmers as a feed supplement, to optimize the proportion of nutrients that are taken up from feed. This helps optimizing their operation costs (as more value can be obtained from a lower volume of product), and at the same time has a positive impact on the environment. Less demand for raw materials, implies reduced production volumes, less energy and water consumption, etc. Alternatively, enzymes can be added directly to the animal feed, as it is often done in connection with feed for monogastric, i.e., animals with only one stomach such as pigs and chickens fed soy-based feed. It is produced more independently of where animal husbandry is located and can be transported over long distances. Similar to enzymes, probiotics are also used as diet supplements (and are often used together), to improve livestock's balance in the gut system. This allows the animals to stay healthy and function effectively.

Typical customer groups include large processors of plant-based products (meat, milk, eggs, etc.), large farmers, feed producers, and distributors, all of similar potential and importance. However, large farmers, although more relevant within cattle holdings, can still be influenced by meat/dairy/egg processors via supply contracts setting requirements to how the livestock is managed.

Many enzymes and alternative proteins producers work across sectors (food and feed) and with various bio-solutions (enzymes, alternative proteins, etc.). Although the market is relatively fragmented, a smaller number of large players, such as AB Enzymes, Advanced Enzyme Technologies, BASF, Enmex, DSM, Aum Enzymes, Adisesso, Dupont, Novozymes, Chr. Hansen, Soufflet Group, etc., account for the largest share of the revenue. They are focused on developing partnerships to consolidate their market position and new product launches (often achieved via acquisitions of R&D companies). Good Food Institute identifies more than 300 established companies producing ingredients or equipment for alternative protein products globally. The majority is specialized in plant-based and inputs, and only a few in alternative proteins through fermentation. More than 70% of these companies operate in North America and/or globally.

A detailed description of application areas, client types, and their characteristics and competition are described in the sections below.

5.1 Deployment areas and typical clients

5.1.1 Enzymes for plant proteins and alternative proteins by fermentation

Plant-based proteins are considered functional ingredients with various roles in food formulations. However, most of the plant-based proteins require modification (e.g., to break down the complexity, presence of anti-nutrient residuals, undesirable tastes, etc.), before they can be applied within the food industry. Modification of plant-based proteins provides the opportunity to make them multi-functional ingredients for food systems by changing their properties and improving functionality. In broad terms, protein modification methods can be obtained by physical, chemical, biological, and other novel methods⁴⁴, where using enzymes is the most common way of biological modification.

In most cases, enzymes used in the food industry are used as processing aids, where they aid in the manufacturing of food or food ingredients, but they do not have a function in the final product.

In the past, the enzymes used in food processing were primarily derived from animal offal and plant material/extracts (where protein isolates are extracted from their plant source). Nowadays, over 90% of the enzymes are obtained through microbial fermentation⁴⁵. **Traditional microbial fermentation** is a well-known technique and involves adding starter cultures (lactic acid bacteria, yeast, mold, etc.) to raw materials such as soya beans. The microorganisms in the starter culture transform the raw materials biochemically (e.g., by developing nutrients) and organoleptically (e.g., taste, texture, etc.)⁴⁶. The market for enzymes obtained through microbial fermentation is a mature field, mostly B2B, with multiple producers and wide product availability. Innovation within this field is mostly related to designing new enzymes feasible for new types of food and applications.

Alternative proteins can also be produced directly via microbial fermentation, skipping both the animal and plant production (and thus also use of enzymes as aids to plant proteins). This can eliminate many production steps, which provides a great saving, not only on CO₂ but also on water and land consumption. A novel and promising technology allowing the production of alternative proteins directly via fermentation are called **precision fermentation**. Microorganisms (e.g., bacteria, algae, fungi, etc.) are programmed to produce complex organic molecules such as proteins, identical to the animal-based ones (e.g., milk or meat proteins)⁴⁷. This technology attracts a great deal of attention, as there is a general perception that this technology has the potential to produce valuable proteins, faster and at a fraction of the current production costs. Another, emerging technology is **biomass fermentation** meaning that the microorganisms (e.g., fungi or algae) are proliferating, and become themselves the key ingredient of the alternative protein. These microbes have the ability to multiply quickly, increasing the amount of available biomass quickly.

While the production of alternative proteins via fermentation is by some considered to be the future of the plant-based meat alternatives industry, this technology has still some significant milestones to achieve before being able to realize its full potential. High costs, price, and relatively low production efficiency (requirements to space for tanks, etc.) are still limiting factors for scalability, and to make this technology applicable for low-value proteins like alternatives to milk-proteins. Consequently, the demand for more traditional plant-based proteins is expected to continue at least in the medium-term before the market starts to be taken over by the more novel technologies such as precision fermentation and biomass fermentation (e.g. cultivated proteins).

The list of existing and potential applications of enzymes for plant proteins and/or alternative proteins obtained via fermentation is long and continuously expanding. However, the most common applications of these technologies within the U.S. food industry include dairy, plant-based alternatives for meat, alternatives to eggs, beverages such as wine and beer, and bread/pastry. All of these industries require enzymes across multiple processing stages, to improve the functionality and nutrition values of plant-based proteins. The use of the more novel fermentation technologies

⁴⁴ Modification approaches of plant-based proteins to improve their techno-functionality and use in food products, Maryam Nikbakht Nasrabadi, Ali Sedaghat Doost, Raffaele Mezzenga, 2021

⁴⁵ Den Store Danske ([https://denstoredanske.lex.dk/enzymer_\(fremstilling_og_anvendelse\)](https://denstoredanske.lex.dk/enzymer_(fremstilling_og_anvendelse)))

⁴⁶ ProVeg Incubator (<https://provegincubator.com/fermentation-a-quick-guide-for-alt-protein-fans/>)

⁴⁷ ProVeg Incubator (<https://provegincubator.com/fermentation-a-quick-guide-for-alt-protein-fans/>)

enabling the production of alternative proteins directly is still limited, but a large potential is assessed across the industries dominated by animal-based proteins, i.e., dairy, meat, and eggs. An overview of the most common applications areas within the U.S. food is presented below:

- **Dairy industry:** In the dairy industry, microbial enzymes are utilized for the production of plant-based milk, cheese, yogurt, ice cream, etc., to improve texture and/or flavor⁴⁸. The most mature segment within the category is plant-based milk (almond-, oat-, soy-, coconut-, pea milk, etc.)⁴⁹. Precision fermentation is considered to have enormous potential within the dairy industry, as it can potentially contribute to significantly faster, efficient, sustainable, and cheaper production of milk and other dairy products than ever done before.
- **Plant-based alternatives to meat:** Natural enzymes are today mostly used within this industry to improve the taste and texture of the plant-based meat alternatives. Plant-based alternatives to animal proteins are increasing in prevalence and quality, but for many applications, they are not currently able to fully emulate the sensory and functional properties of animal proteins. E.g., the “umami” is difficult to mimic in plant-based meat alternatives, especially if the salt content needs to stay low⁵⁰. Precision fermentation seeks to solve this problem directly by producing genuine animal proteins through fermentation.
- **Alternatives to eggs:** Enzymes are used to improve the texture and nutrition values of plant alternatives mimicking egg whites. Furthermore, similarly to the dairy industry, a significant potential is assessed in the production of animal-free egg proteins via precision fermentation when this technology matures⁵¹.
- **Beverages (beer, wine, etc.):** Both wine and beer are produced by yeast fermentation of sugars⁵². Enzymes produced by various microorganisms (bacteria, fungi, and yeasts, etc.) are used at all stages of grape cultivation and wine production (e.g., to improve maceration, clarification, filtration, yield, aroma, etc.). Similarly, various enzymes are used across beer production stages.
- **Baking industry:** Enzymes are broadly used in the baking industry for products like bread, cookies, etc. during multiple steps of production. They are typically utilized to enhance the baking quality, nutritional quality, texture, stockpiling resistance, and improve the nature of wheat flour (lower the protein level). For example, amylases (starch-digesting enzymes) can be used to speed up fermentation and give a fluffier texture.

Typical customer groups include traditional food production giants, producers of plant-based alternatives, and distributors, all potentially being both clients and competitors. While distributors would be most relevant for less complex products, food producers (both traditional and plant-based) are also relevant for the more innovative solutions. While the large food giants and the more traditional producers of plant-based food that use the enzymes to improve quality are the most obvious client groups at the moment, potential untapped applications are seen within the current generation of innovative plant-protein products, that still use synthetic/unnatural additives to improve the functionality of their products. Overview of client types, their characteristics, and examples are shown in the table below.

⁴⁸ Abada, 2019: 62

⁴⁹ ‘2020 was a breakout year for plant-based foods...’ GFI, PBFA, SPINS, unveil 2020 retail sales data (foodnavigator-usa.com)

⁵⁰ Labiotech.eu

⁵¹ <https://www.foodnavigator.com/Article/2021/02/09/Clara-Foods-on-cracking-the-world-s-first-animal-free-egg-white>

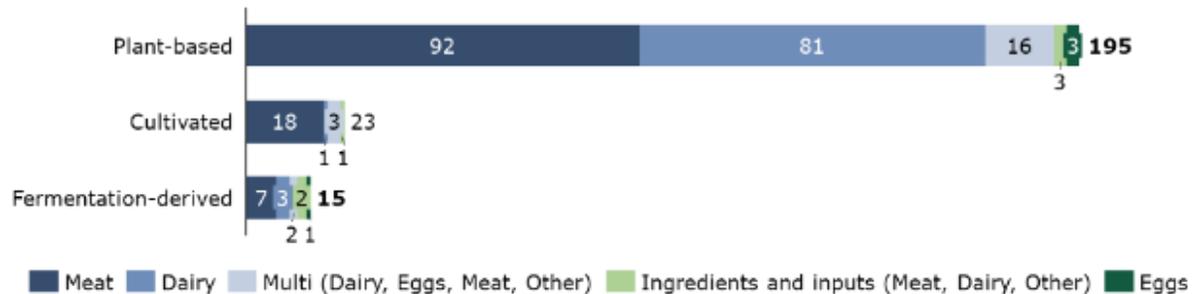
⁵² Enzymes Used In Brewing Process | Infinita Biotech

Table 2: Typical clients – Enzymes for plant proteins and/or alternative proteins

	Traditional food production giants seeking offer expansion	Pure plant-based products producers	Distributors
Customer description	<p>Seek new innovations that can help them to stay competitive in the changing market (consumer preferences changing towards animal-free, healthy, and clean label foods, and the general climate agenda).</p> <p>High focus on research and innovation activities.</p>	<p>Companies specializing in the production of plant-based food, including:</p> <ul style="list-style-type: none"> Specialized in more traditional and commercialized techniques (e.g., sausages, etc. based on plant-proteins processed using enzymes, e.g., to improve taste) Innovative companies that apply more novel techniques to produce plant-based food (both mimic meats etc. but also other alternatives). The group does not include new generation technology companies that produce all-natural and fully sufficient products, which do not require enzymes or alternative proteins to improve the final functionality or sustainability of their own products. 	<p>Legacy companies specialized within a specific area or with a strong geographical presence in a given location can partner up with a bio-solution provider (mostly enzymes) to distribute their products across the country. Distributors can be both global or local and can be specialized e.g., within color or texturing (e.g., using chemical solutions).</p> <p>Distributors will typically be approached for less complex products (e.g., more traditional enzymes) that are sold in large volumes when the bio-solution producer does not have its own sufficient infrastructure. Distributors are also in some cases used for "light-house" products (products in new areas) from larger bio-solution producers, where the new sub-organizations do not have sufficient staffing to do distribution on their own.</p> <p>Distributors can also be agents, i.e., purchasing technology and distributing to retailers or food-producers.</p>
Products	Produce plant-based food that is sold to end-consumers, primarily via retail.	Produce plant-based food that can be sold via retail and restoration industry (both high-end restaurants and fast-food).	Sell products within a similar range as enzyme producers (e.g., synthetic/chemical additives) via such channels as retail, online, etc. Some other distributors can be only B2B.
Their needs	<p>Can be both clients and competitors for enzymes and alternative proteins producers, i.e., often have their own R&D activities (incl. investments in bio-solution companies), but also buys enzymes, and other bio-solutions, especially when developing on their own is associated with large investments and high risks (e.g., patented technologies). An example is Tyson Foods, which is a large purchaser of various forms of enzymes, but the corporation has also invested in the U.S. plant-based burger firm Beyond Meat and backed two lab-based meat firms – Memphis Meats from the U.S. and Future Meat Technologies.</p> <p>Mostly interested in products that mimic the regular products (e.g. meat), as their target clients are not vegetarians/vegans, but rather normal meat consumers who wish to vary their diet with plant-based food.</p>	<p>Can be both clients and competitors, i.e., can either be the buyer of bio-solution and apply them in their products, or producers of competing solutions (in some cases with the potential to become customers).</p> <p>The first group, the more traditional plant-based food producers are in many cases existing bio-solution buyers.</p> <p>The second group, the novel technology producers (e.g., Beyond Meat) is considered to have a large untapped potential. Many of these producers are still using synthetic additives (e.g., to improve taste), making their product less sustainable than broadly perceived. In line with the new generation of innovative technology, this is expected to improve, however, in the short and medium term, this group could have large potential for enzyme and alternative proteins providers.</p>	Can be both clients and competitors, i.e., can buy the proteins to sell via own channels (e.g., to diversify portfolio), but will in many cases also sell competing products (e.g., synthetic alternatives).
Customer examples	Tyson Foods, Nestlé, Cargill, General Mills, OSI Group, Rastelli Foods Group, e.g., Ben & Jerry's.	<p>Plant-based meat products: Beyond meat, The Kraft Heintz Company, Dr. Praeger's, Maple Leaf Foods, Impossible Foods, etc.</p> <p>Plant-based dairy: milk, yogurt, creamer, ice cream: HP Hood, Califia Farms, Planet Oat, etc.</p>	Brenntag, IMCSzyme, etc.

Based on the GFI’s database for the alternative protein manufacturers and brands⁵³, the majority of the alternative proteins manufacturers and brands are within the alternative meat and dairy industry. Furthermore, most of these companies are working with more traditional techniques (production of plant-based products using enzymes) and are located in California⁵⁴.

Figure 4: Overview of alternative protein manufacturers and brands in the US



Note: The list is not exclusive, excludes outliers and companies difficult to categorize. However, we consider it a good indicative illustration of the distribution within the market.

Sources: Good Food Institute, Ramboll analysis

5.1.2 Digestive enzymes and probiotics for animal feed

Animal feed is typically the largest cost item in the operation of livestock, accounting for 60-70% of the total operational expenses⁵⁵.

When animals digest their feed, enzymes in their stomachs break down the starch, protein, and fats into their components, which are then absorbed as vital nutrition. However, not all of the feed can be digested, and a large share becomes a waste. When used as feed supplements, enzymes speed up digestion and optimize chemical processes responsible for converting nutrients into energy and new tissue, meaning that fewer grains are needed to be purchased and processed. Furthermore, they improve the overall digestibility of by-products such as wheat, corn, or grain conceivable as a supplement to other more expensive inputs in the animal’s eating regimen⁵⁶.

A large share of enzyme supplements on the market today contains enzymes derived from animal sources. However, dietary supplements containing enzymes obtained from non-animal sources have become increasingly more popular due to the advantages such as the possibility to obtain a higher concentration of the enzyme product, a broader spectrum of digestive activity working on all of the main food components (protein, carbohydrates, fat, and fiber), higher stability in the acidic environment and a better ability to control the sustainability aspect (many of animal-derived enzymes are obtained from slaughterhouse pigs or cows, fed with steroids, antibiotics, etc.)⁵⁷.

Feed for animals such as cattle is often produced locally with enzymes being used as diet supplements. Feed for monogastric (poultry, pigs, etc.) is mainly soy-based, and can be transported for long distances (e.g., pig feed in Denmark is imported for Latin America or the U.S.). Adding enzymes directly to the feed for monogastric (e.g. poultry and hogs) at the production stage (which is often remote from the livestock location) is common.

Another supplement commonly used together with the enzymes is probiotics. Digestive enzymes and probiotics work together but are two different things. While enzymes are active but non-living molecules that speed up digestion and optimize chemical processes within the digestive system,

⁵³ <https://gfi.org/resource/alternative-protein-company-database/>

⁵⁴ Good Food Institute

⁵⁵ Becker, G. (2012): “Livestock Feed Costs: Concerns and Options”

⁵⁶ <https://infiniabiotech.com/blog/benefits-of-enzymes-in-animal-feed/>

⁵⁷ <https://www.enzymesinc.com/vegetarian-vs-animal-enzymes/>

probiotics are living organisms (bacteria) that help balance the environment of the gut, so it can stay healthy and work efficiently⁵⁸.

Typical customer groups include large processors of meat, milk, eggs, etc., large farmers, feed producers, and distributors, all of similar potential and importance. However, large farmers, although more relevant within cattle holdings, can still be impacted by meat/dairy/egg processors via supply contracts. Overview of client types, their characteristics, and examples are shown in the table below.

Table 3: Typical clients – Digestive enzymes and probiotics for animal feed

	Large meat, dairy, and egg processors	Large farmers	Feed producers	Distributors
Customer description	A large share of the U.S. livestock industry is vertically integrated, meaning that large meat producers (e.g., slaughterhouses) own the animals as well (even if they are physically located at the farmers). This is especially relevant in the case of poultry and the pig industry.	Cattle holdings are the least vertically integrated livestock industry in the U.S. to date, meaning that farmers own their animals, and have in many cases a higher degree of autonomy when it comes to operations and deciding which products (e.g., feed) to use. However, note that in some cases, farmers will still be on contracts with large meat/dairy producers, setting requirements to their diet composition.	Producers of feed (e.g., soy-based for monogastric), that is commonly distributed all over the country and not necessarily produced locally.	Legacy companies specialized within a specific area or with a strong geographical presence in a given location can partner up with a bio-solution provider (e.g., enzymes or probiotics) to distribute their products across the country. Distributors can be both global or local and can be specialized e.g., within color or texturing (e.g., using chemical solutions). Distributors can also be agents, i.e., purchasing technology and distributing to retailers or food-producers.
Their needs	Use enzymes and probiotics as dietary supplements.	Use enzymes and probiotics as dietary supplements.	Add enzymes to the feed, which is then distributed to the farmers locally or globally.	Buy enzymes from the producers to extend and diversify own assortment. Can provide the enzymes directly to the large meat, dairy, and egg producers.
Customer examples	DFA Facilities, Cargill, Tyson Foods, JBS USA Holdings.	Harris Ranch, Deseret Ranches, and Dairy Farmers of America.	Alltech, Land O’Lakes, Cargill, Tyson Foods, and ADM Animal Nutrition.	Brenntag, IMCSzyme, etc.

5.2 Competitive landscape

Many enzymes and alternative proteins producers work across sectors (food and feed) and with various bio-solutions (enzymes, alternative proteins, etc.).

Both the global and the North American enzymes market is relatively consolidated, with several large players focused on consolidating their market position through partnerships, acquisition of other companies, investing in their R&D facilities, new product launches, etc., and multiple smaller companies and start-ups focused on innovation and R&D.

⁵⁸ What You Should Know About Digestive Enzymes vs. Probiotics (omnibioticlife.com)

According to Good Food Institute’s database, there are more than 300⁵⁹ established companies producing ingredients or equipment for alternative protein products globally⁶⁰. The vast majority (more than 75%) of companies are specialized in ingredients and inputs. Of these, more than 70% operate in North America or globally⁶¹. Some of the major players in the market are AB Enzymes, Advanced Enzyme Technologies, BASF, Enmex, DSM, Aum Enzymes, Adisesso, Dupont, Novozymes, Chr. Hansen, Soufflet Group, etc.⁶².

Table 4: Companies producing ingredients or equipment for alternative protein products

Company focus	# of companies	Share of total
Ingredients and inputs	249	77%
Processing infrastructure and equipment	40	12%
Contract manufacturing/processing	24	7%
Bioprocessing infrastructure and equipment	2	1%
Other	10	3%
Total	325	100%

Source: Good Food Institute

In line with new players entering the market, the competition is expected to intensify, expectedly having a positive impact on innovation, affordability, and thus also the market growth.

A long list of companies specialized in plant-based ingredients and inputs and operations in North America and globally is shown in appendix 1 (note, the list is an extract from the Good Food Institute database and is potentially not exhaustive).

⁵⁹ Only companies viewed by GFI as having focus on alternative protein applications are included in the database.

⁶⁰ Good Food Insistute Database 2021: Companies producing ingredients or equipment for alternative protein products

⁶¹ Good Food Insistute Database 2021: Companies producing ingredients or equipment for alternative protein products

⁶² Mordor Intelligence

6. KEY OPPORTUNITY SPACES

The purpose of this analysis is to assess the attractiveness of the various offtake markets, based on quantitative and qualitative indications of market size and growth potential. This is combined with an assessment of various states to identify the most interesting geographies and ultimately define key opportunity spaces based on these two analyses. The identified opportunity spaces are further analyzed in the next chapter to identify the most relevant stakeholders and potential partners.

Although the analysis focuses on the two tracks enzymes for plant proteins and alternative proteins via fermentation and digestive enzymes and probiotics for animal feed, many of the conclusions will also be valid for a broader range of bio-solutions targeting the food and/or agricultural sectors.

Following conclusions have been derived on the attractiveness of the individual markets:

- Within the food track using enzymes to improve the functionality of the plant-based meat and dairy are considered the most promising deployment areas, as this technology is believed to be capable to unlock the significant untapped potential within this market (currently constrained by the parity issues) already within the short to medium run. Although alternative proteins derived via fermentation are believed to be a ground-breaking solution on how to mimic animal-based proteins to perfection, this technology has still some significant milestones to reach before it can become fully competitive on price with e.g. the enzyme-technology.
- Within the feed track, the highest potential is observed within digestive enzymes and probiotics to improve the efficiency of the cattle feed, as the deployment of this technology is assessed to be fairly behind to what is observed within e.g. the poultry industry. Driven by the growing pressure on cost and operations efficiency within this industry and the increasing awareness of benefits connected to the use of enzymes and probiotics, the market is expected to start unlocking soon. Although the potential is assessed highest within the cattle industry, the other livestock groups, i.e. poultry and hogs are also considered attractive and high-growth markets, although the overall growth rates here are expected to be lower than in the cattle industry.
- The most attractive states for the deployment of bio-solutions in scope are assessed to be California, New York, Massachusetts, and Illinois for the food track and Midwest states, Oklahoma, Texas, and California for the feed track. The attractiveness of these states is driven by the overall supportive environment, comprising proximity to clients, knowledge centers, and political encouragement of bio-solutions.

Moreover, the assessment has resulted in the definition of three key opportunity spaces: 1) Deployment of enzymes as ingredients to plant-based meat in California, 2) Deployment of enzymes as ingredients to plant-based dairy in California, and 3) Deployment of enzymes to optimize feed efficiency for cattle/beef in California.

All of these opportunities are associated with potentially large and in most cases untapped market potential, that can possibly be unlocked by bio-solutions. While obtaining alternative proteins directly via fermentation has significant potential in the longer run, the application of enzymes to improve the functionality of plant-based proteins is considered the most attractive technological option within the short to medium run.

Other states were considered to be relevant as well, e.g., New York, Illinois, Midwest states, etc. However, the bio-solutions market is assessed to be particularly favorable in California. It is an attractive market with strong purchasing power, demand for innovative and green solutions, heavy R&D focus, and a strong presence of B2B companies that are relevant client segments for enzymes. It is also a large agricultural area focused on cattle holdings. These advantageous conditions outweigh the somehow stricter regulation (mainly on the health claims) that is the case in some other states.

Detailed assessment of the market size and growth potential, attractive states, and opportunity spaces is presented in the following sections.

6.1 Indicative market size and growth

6.1.1 Enzymes for plant proteins and alternative proteins via fermentation

The market size and outlook for enzymes for plant proteins and alternative proteins via fermentation are assessed by examining the development in sales of plant-based protein products. The development in sales of plant-based proteins is considered by Ramboll to be a good proxy of the market size and outlook of food ingredients, as there is assumed a positive relationship between these categories.

The analysis will differentiate between different off-taker markets to specify the areas with the greatest potential. The off-taker markets in focus are plant-based dairy, meat, and eggs as they dominate the U.S. alternative-protein market.

In our assessment, we apply market data obtained from existing market intelligence triangulated across various data sources (interviews, internal expertise, etc.).

Plant-based proteins market in general

Plant-based proteins can be deployed in several industries, including plant-based substitutes for meat, dairy, eggs, and other smaller categories (e.g. protein powder).

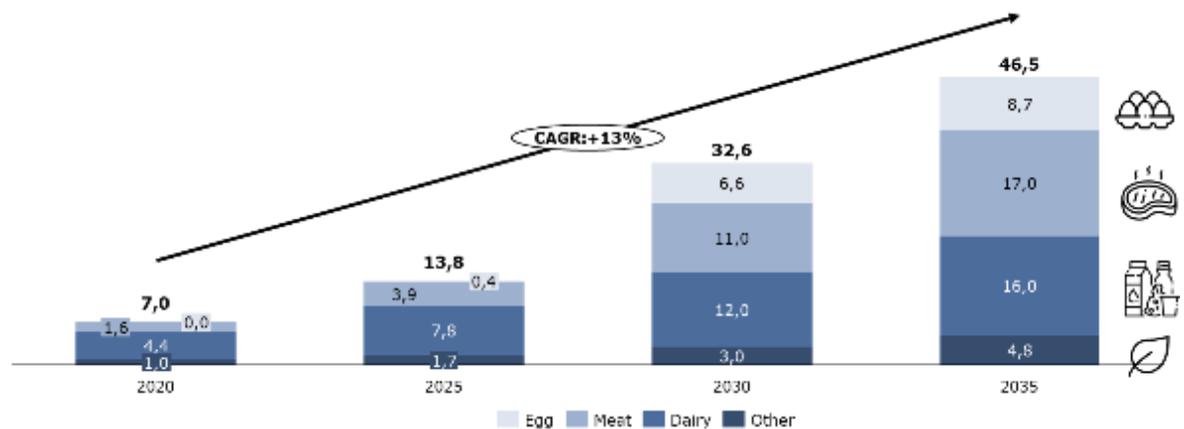
The U.S. plant-based protein market has experienced a rapid increase in sales during the last few years. It grew by 43% between 2018 and 2020, reaching a market size of 7 billion USD, equivalent to ~1% of the total retail food sales and ~3% of the total retail protein market⁶³. In comparison, the overall U.S. retail food market grew by 17% within the same period⁶⁴.

On the product category level, plant-based dairy has an estimated share of ~6% of the total U.S. dairy market, whereas both the plant-based meat and egg alternatives only have a penetration rate of ~2%⁶⁵. A slightly higher market share of plant-based dairy products can be attributed to the overall maturity of the market. Plant-based dairy products are in most cases used as meal ingredients, making consumers more tolerant to adopt them.

Within the plant-based market, the plant-based dairy industry accounts for ~63%, making it the largest sub-industry at the moment. Plant-based meat accounts for ~23% and egg alternatives account for less than 1% of the market.

The U.S. plant-based food market is expected to grow nearly seven-folded, to ~47 billion USD between 2020-2035, with an average growth rate of ~13% each year⁶⁶.

Figure 5: Plant-based proteins market outlook, 2020-2035 (Billion USD)



Sources: Good Food Institute, SPINS, Ramboll analysis

⁶³ Statista (2021): U.S. food retail industry

⁶⁴ SPINS (2020)

⁶⁵ SPINS (2020)

⁶⁶ Good Food Institute, SPINS, Ramboll analysis

Today, the U.S. meat market is the largest sub-market within the animal-based protein industry (~110 billion USD), followed by the dairy market (70 billion USD)⁶⁷. However, there is a large disparity between the market share of plant-based meat and plant-based dairy alternatives. This is mostly due to the fact that consumers buying plant-based dairy (and especially milk) are more tolerant in terms of the product not being a perfect mimic of the animal-based alternative. Buyers of the plant-based meat alternatives have in many cases higher requirements to the parity on taste, texture, etc. With the increasing focus on sustainability, health concerns, and technological development, large and untapped potential is assessed within the plant-based meat alternatives.

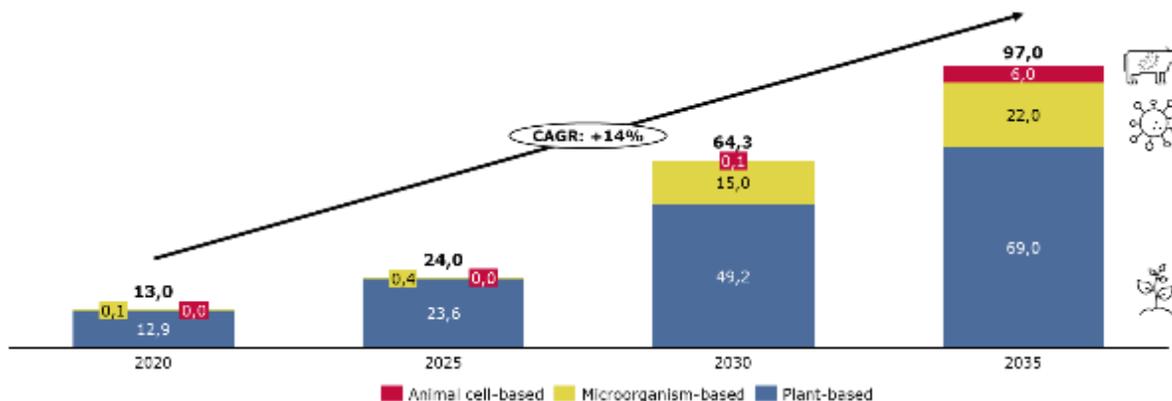
Even though the dairy and egg markets are smaller than the meat market, the significant potential is assessed also within these markets, but in the longer term for plant-based egg alternatives.

Alternative proteins can be either plant-based (where enzymes are used to improve functionality, i.e. taste, texture, etc.), microorganism-based (where microorganisms produce enzymes that are alternative proteins and not only ingredients), and animal cell-based (i.e. cultivated products).

The largest potential within the short to medium term is assessed to be within the plant-based proteins market. The market is currently dominating the alternative proteins technologies with nearly a 100% market share and it is expected to keep the high growth rate in the short-medium term but also potentially in the longer run (15+ years).

Although high investments within the alternative protein industry are driving advancements in new and innovative technologies, the majority of alternative proteins is expected to be based on plant-based proteins within the short to medium run. Microorganism-based proteins are not expected to gain substantial market traction before 2030, while animal-cell-based proteins are still in very early development and are not expected to be of significant volumes during the next decade.

Figure 6: Protein technology market development, 2020-2035 (Million metric tons)



Sources: BCG, Blue Horizon, Ramboll analysis

Plant-based dairy market

The plant-based dairy market is mostly comprised of plant-based products such as milk, cheese, yogurt, etc.

With a U.S. market size of 4.4 billion USD in 2020, it is the largest plant-based sub-industry⁶⁸. In general, plant-based milk has already a relatively high market share of the total U.S. milk industry, equivalent to ~15% and 2.5 billion USD⁶⁹. In comparison, plant-based cheese accounts for only ~1%, and plant-based yogurt accounts for ~4%⁷⁰ of total respective markets (both animal-based and plant-based).

⁶⁷ Good Food Institute, SPINS, Ramboll analysis

⁶⁸ SPINS & Good Food Institute

⁶⁹ SPINS (2020)

⁷⁰ SPINS (2020)

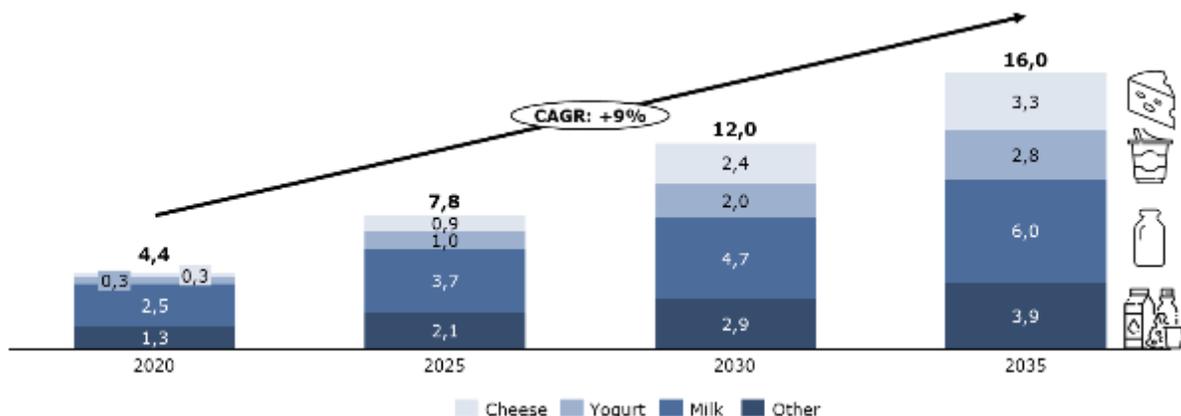
The success of plant-based milk can be attributed to the highly developed sales channels of these products in the U.S. and meeting taste and texture requirements making it easy for people to use the product. Note, that many of the consumers buying plant-based milk are not seeking the perfect mimic of the animal-based milk, which also makes this product highly adaptable.

The plant-based yogurt and cheese have not yet succeeded in meeting the consumers' requirements on taste and texture. The key challenge is that many of the manufacturers of these products are focusing on how to perfectly mimic a few characteristics of the dairy alternative, instead of making them an enjoyable alternative.

While the plant-based dairy industry is currently mostly driven by the milk category, moving forward, both the yogurt and cheese categories are expected to have a more significant impact on this industry's growth. They are on average expected to increase by ~15% and ~18% each year, respectively, compared to ~9% annual growth in the plant-based dairy industry⁷¹. With technological developments, these two markets can catch up on the success of plant-based milk.

The long-term expectation is that all of the plant-based dairy categories will eventually account for ~20% of the market within each dairy category⁷². Thus, as there is a large gap within the plant-based cheese and yogurt categories, they are associated with high, but still untapped opportunities. However, the highest potential is still assessed within the plant-based milk category, due to the high expected volumes within the category, increasing in line with the growing population, increasing demand for proteins, and more conscious consumers.

Figure 7: Plant-based dairy proteins market outlook, 2020-2035 (Billion USD)



Sources: BCG, SPINS, Good Food Institute, Ramboll analysis

Plant-based meat market

Animal-based meat proteins are an important part of the American diet. Each year, U.S. households spend approximately half of their annual food budget on animal meat proteins⁷³.

The U.S. market of the plant-based meat industry (entailing plant-based alternatives to beef, chicken, pork, etc.) was estimated 1.6 billion USD in 2020, equivalent to ~1% of the total meat retail sales⁷⁴.

It is expected that between 2020 and 2035, the plant-based meat market will on average grow by 17% each year, i.e. almost twice the growth rate of the plant-based dairy market (9%)⁷⁵.

Figure 8: Plant-based meat proteins market outlook, 2020-2035 (Billion USD)

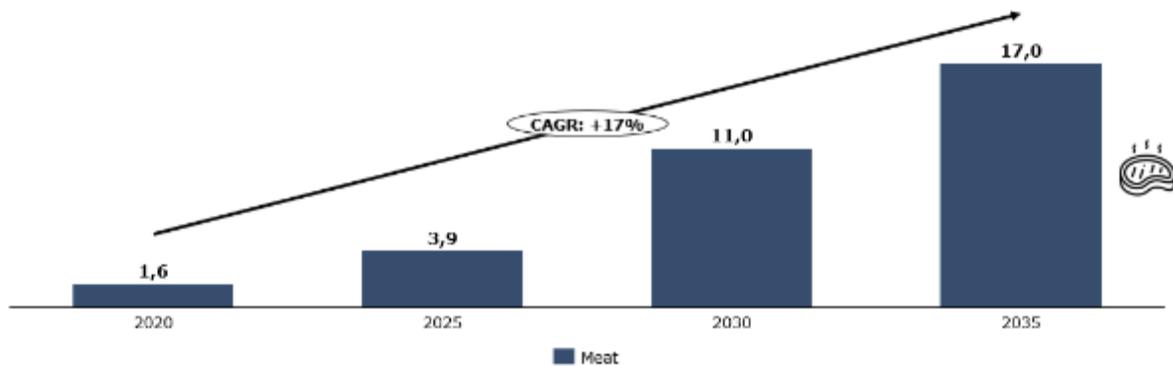
⁷¹ BCG, SPINS, Good Food Institute, Ramboll analysis

⁷² Chr. Hansen

⁷³ McKinsey (2018): How the global supply landscape for meat protein will evolve

⁷⁴ BCG, SPINS, Good Food Institute, Ramboll analysis

⁷⁵ BCG, SPINS, Good Food Institute, Ramboll analysis

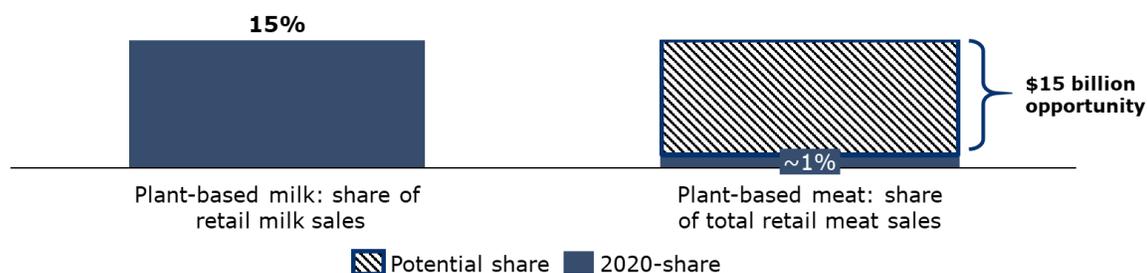


Sources: BCG, SPINS, Good Food Institute, Ramboll analysis

However, advancements in the parity of taste, texture, and price of plant-based products will be necessary to secure market growth. To illustrate this, in 2020, ~18% of all U.S. households had purchased plant-based meat products (an increase of ~25% from the year before), but only ~60% of the households had repeated their plant-based protein purchases⁷⁶.

With the market becoming more mature and the technology advancements closing the parity gap between plant-based and animal-based products, the plant-based meat industry has the potential to reach a market share equivalent to that of plant-based milk in the long-medium run, i.e. 15%⁷⁷. The ~14% gap between the current and the potential market share is estimated at ~15 billion USD⁷⁸. However, some experts believe that plant-based meat can replace one-third of all meat consumption by 2030⁷⁹. Thus, by investing in improving bio-solution technologies, plant-based meat companies can tap into this huge unrealized market potential.

Figure 9: Plant-based milk & meat market share of total categories in 2020



Sources: BCG, SPINS, Good Food Institute, Ramboll analysis

Plant-based eggs market

The plant-based eggs market consists of all the products substituting the application areas of traditional eggs (e.g. baking, dips, food, etc.). Today, the market of plant-based eggs is still modest with 27 million USD in sales in the U.S.

North America is currently the largest market for plant-based egg alternatives⁸⁰. The plant-based egg industry is expected to grow by ~47% annually from 2020 to 2035⁸¹, making it the fastest-growing category across the entire plant-based market. As a result, it will increase the market share of total plant-based sales from less than 1% to ~19% by 2035⁸². However, the majority of

⁷⁶ Good Food Institute (2020)

⁷⁷ Chr. Hansen, Good Food Institute, Ramboll analysis

⁷⁸ BCG, SPINS, Good Food Institute, Ramboll analysis

⁷⁹ Kearny (2019)

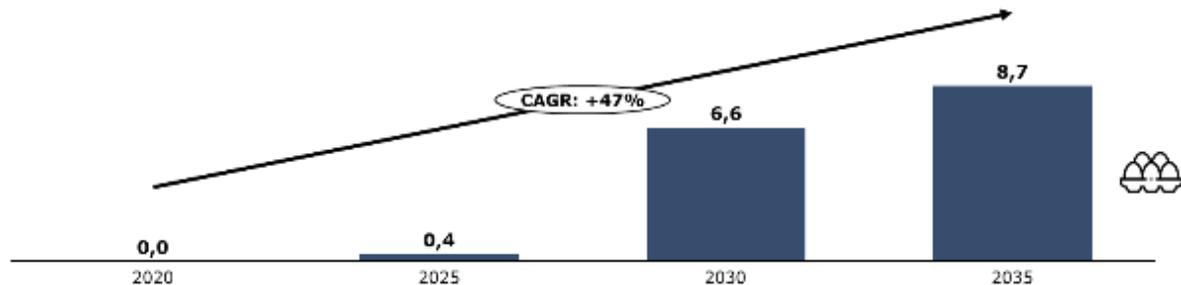
⁸⁰ Proveg (2021)

⁸¹ SPINS, Good Food Institute, Ramboll analysis

⁸² SPINS, Good Food Institute, Ramboll analysis

the growth is expected to happen from 2025, as reaching the necessary functionality parity for this product remains a challenge, and it is first expected to be solved by more innovative technology (e.g. precise fermentation)⁸³.

Figure 10: Plant-based egg proteins market outlook, 2020-2035 (Billion USD)



Sources: SPINS, Good Food Institute, Ramboll analysis

6.1.2 Digestive enzymes and probiotics for animal feed

Market attractiveness for digestive enzymes and probiotics has been assessed by examining quantitative data points on feed consumption within different animal groups, combined with qualitative insights on the current application rate of enzymes and the expected growth potential. Although this methodology does not provide precise market size, and the relationship between enzyme demand and livestock inventory will not necessarily be completely linear (the optimized feed conversion ratio will ultimately decrease the need for feed), it is deemed to give a valuable indication of market attractiveness and potential within each segment (animal category).

The analysis does not differentiate between enzymes and probiotics as developments in their applications are expected to follow a similar trend. According to some of the interviewed market players, digestive enzymes are often complementary to probiotics, and farmers adopting one of the solutions are considered likely to adopt the other as well.

Furthermore, opposite to the plant-based proteins, the market attractiveness is assessed based on volumes and not on monetary value, as the price levels are assessed to vary significantly within the categories and are in many cases highly customized.

The assessed sub-market includes holdings of cattle, poultry, and hogs as these are the most predominant livestock groups in the U.S. Approximately 96% of all animal-based protein supply origins these three livestock categories⁸⁴.

Animal feed market

Animal feed consumption is growing in line with livestock holdings, driven by increasing demand for proteins (due to the increasing and wealthier population).

While farmers are looking into new ways of increasing feed conversion ratios and decreasing costs, it is further intensified by growing climate concerns and a focus on more efficient agriculture. At the same time, the growing health concerns among U.S. consumers are changing their preferences towards healthier and more “clean” food. Hence, the entire supply chain has to adjust by replacing chemical ingredients with natural ingredients.

Cattle accounted for ~42% of the total animal feed consumption in 2020, making this group the largest consumer of feed (poultry accounts for ~29% and hogs for ~23%)⁸⁵.

While application of digestive enzymes is already common practice within some sub-categories, e.g. poultry, it is still less widespread within cattle production. However, the awareness of the potential benefits of using digestive enzymes and probiotics to optimize feed in cattle operations is

⁸³ BCG & Blue Horizon

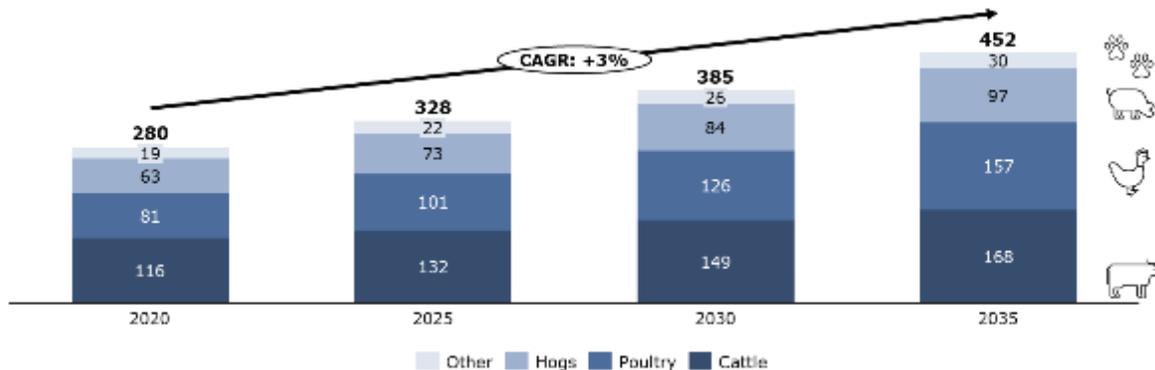
⁸⁴ McKinsey (2018)

⁸⁵ American Feed Industry Association

increasing, resulting in more farmers gaining knowledge of the technology, and thus the major potential for enzymes and probiotics.

The U.S. feed market is expected to grow by an average of 3% per year between 2020 and 2035⁸⁶, with the growth rate relatively evenly spread across the categories.

Figure 11: Animal feed consumption market outlook, 2020-2035 (million tons)



Sources: American Feed Industry Association, Mordor Intelligence, Research & Markets, Ramboll analysis

Poultry Sector

The U.S. poultry consumption of feed was estimated at 81 million tons in 2020, making it the second-largest category⁸⁷.

However, the poultry segment is projected to be the fastest-growing segment between 2020 and 2035, driven by the high increase in consumption of chicken proteins. By 2035, the poultry feed consumption is expected to reach 157 million tons which is equivalent to average annual growth of ~5%⁸⁸.

The use of digestive enzymes to optimize feed conversion ratio is more common within the poultry market than in any other animal type. Poultry (and hogs) have traditionally been the key applications segments for digestive enzymes and probiotics, as they are monogastric animals with difficulties digesting more than 75% of their diet. Furthermore, the application of digestive enzymes has a proven effect of improving the bodyweight of poultry resulting in more profitable operations⁸⁹. Globally, the application of enzymes within the poultry segment accounts for ~45% of the total feed enzymes market⁹⁰.

The market is relatively mature, and enzymes are often applied directly to the feed at the feed production stage. Consequently, the market growth is mainly expected to be the result of increasing poultry inventories.

Hog Sector

The U.S. hogs have consumed ~63 million tons of animal feed in 2020, which is expected to increase to ~97 million tons in 2035 (equivalent to average annual growth of ~3%)⁹¹.

Similarly to poultry, enzymes are commonly used in hogs/pigs to improve feed digestion.

Due to the relatively low absolute growth in hog feed consumption and the fact that the market is already relatively mature, the overall potential is assessed lower than for the remaining segments (poultry and cattle).

⁸⁶ American Feed Industry Association, Mordor Intelligence, Research & Markets, Ramboll analysis

⁸⁷ American Feed Industry Association

⁸⁸ American Feed Industry Association, Mordor Intelligence, Research & Markets, Ramboll analysis

⁸⁹ Ojga, B.K., et al. (2019)

⁹⁰ Future Market Insights (2020)

⁹¹ American Feed Industry Association, Mordor Intelligence, Research & Markets, Ramboll analysis

Cattle sector

According to the Food and Agriculture Organization (FAO), the U.S. cattle inventory has declined by approximately 135 million heads since 1970, to ~92 million heads in 2016. However, driven by the increasing demand for both meat and milk, the trend has reversed starting in 2016, increasing to ~101 million heads in 2021⁹².

The cattle feed consumption was estimated at ~116 million tons in 2020, and it is expected to grow by ~45% towards 2035 (to ~168 million tons)⁹³.

While being the largest feed market, the application of enzymes as supplements to feed in cattle is far less widespread than in the case of poultry and hogs. Formerly, the literature has been filled with conflicting conclusions on the effectiveness of exogenous digestive enzymes on ruminants (e.g. cattle). However, more recent research confirms the benefits of exogenous enzymes are apparent for ruminants⁹⁴. Farmers are currently being increasingly aware of the benefits of digestive enzymes and probiotics on cattle operations, meaning that this market has possibly the largest, and still untapped potential.

6.2 The most attractive states

Attractive states are identified through a qualitative criteria-based screening approach. The criteria underlying the state selection are derived based on the assessment of market drivers, application areas, and market attractiveness, and contain both quantitative and qualitative data points.

Following criteria have been applied to identify the most attractive states for the deployment of [enzymes for plant proteins and alternative proteins via fermentation](#):

 **Table 5: State selection criteria for enzymes and alternative proteins via fermentation**

	Criteria	Short description and relevance
Typical buyers of alternative proteins	Education level	People with higher education levels are more likely to be consumers of alternative proteins. Hence, we are screening on the share of people in each state with a bachelor’s degree or higher.
	Income level	The typical consumer of alternative proteins has a high-income level. To assess that, the individual median income in each state has been compared.
	State population	States with large populations have potentially a larger consumer base.
Other conditions	State innovation index	Proxy for the state’s maturity in adopting new technology. It is an equally-weighted average based on six metrics: research and development intensity, productivity, clusters of companies in technology, STEM jobs, residents with degrees in science and engineering disciplines, and patent activity ⁹⁵ . The more mature a state is to adopt new technology; the higher market potential is expected for bio-solutions.
	Alternative protein manufacturers	The manufacturers are potential clients of bio-solution organizations. Hence, the more concentrated the manufacturer market is, the larger is the potential market for bio-solutions.
	Regulation and incentives	Regulation can act both as a barrier and an enabler for bio-solutions within the alternative proteins. State regulation can make it more favorable for bio-solution organizations to locate in one state over another due to e.g., tax advantages or labeling barriers.

Following criteria have been applied to evaluate the attractiveness of individual states in relation to the [digestive enzymes and probiotics for animal feed](#):

⁹² USDA (2021)

⁹³ American Feed Industry Association, Mordor Intelligence, Research & Markets, Ramboll analysis

⁹⁴ Roque, B. et al. (2017)

⁹⁵ Bloomberg (2020)



Table 6: State selection criteria for digestive enzymes and probiotics for animal feed

Criteria	Short description and relevance
Cattle stock distribution	During our research, it was found that the largest potential has been assessed with regard to the cattle holdings. As most of the cattle feed is produced locally, with enzymes being applied locally as well, states with large cattle holdings are considered more attractive.
Top 10 agricultural university	States with universities specialized in agriculture have great collaboration opportunities as well as provide a highly skilled workforce.
Regulation and incentives	Regulation can act both as a barrier and an enabler for bio-solutions within digestive enzymes and probiotics for animal feed. State regulation can make it more favorable for bio-solution organizations to locate in one state over another due to e.g. tax advantages. In the case of this track, meat labeling restriction can be viewed as positive, as it shows that the farming sector is particularly strong in such a state.
State Innovation Index	Proxy for the state’s maturity in adopting new technology. It is an equally-weighted average based on six metrics: research and development intensity, productivity, clusters of companies in technology, STEM jobs, residents with degrees in science and engineering disciplines, and patent activity ⁹⁶ . The more mature a state is to adopt new technology; the higher market potential is expected for bio-solutions.

Based on the screening criteria above, Ramboll has identified a group of states that are considered the most attractive in relation to bio-solutions within each track.

In relation to [enzymes for plant proteins and alternative proteins via fermentation](#), Ramboll has identified 4 states that score high on all of the criteria: [California](#), [Illinois](#), [New York](#), and [Massachusetts](#). All of the selected states are characterized by high income and high education levels, with a high concentration of alternative protein manufacturers, which drives the demand for enzymes. Lastly, there are beneficial incentives as the local government specifically targets biotechnology with tax credits and investments.

Within the second track, the [digestive enzymes and probiotics for animal feed](#), states identified as the most attractive include some of the [Midwest states](#), [Oklahoma](#), [Texas](#), and [California](#). All of these states have large cattle holdings, research and knowledge hubs, and regulatory conditions favoring the agricultural sector. Especially in the Midwest, strong agricultural industry organizations are driving the political agenda, which helps farmers obtain political support to make production more effective and sustainable.

⁹⁶ Bloomberg (2020)



Table 7: Attractive states – Enzymes for plant proteins and alternative proteins via fermentation (1/3)

State	Pop. 2020 (millions)	Pop. growth	Share w/ high education*	Median income (USD)	Weighted rating**	State innovation index	# of alt. protein manufactures	Incentives & regulation	Attractiveness
New Jersey	9.3		40 %	51,510	1	72	7	• Incentives to bioscience investors (state tax credits); Provide state investments in bioscience companies through funds of funds	
New York	20.2		37 %	46,020	2	64	27	• New York has introduced the LifeSci NYC Initiative to spur company creation and training and jobs placement	
Massachusetts	7.0		44 %	53,017	3	94	6	• The state of Massachusetts has passed several projects and incentives to accommodate bio-solution organizations. This includes investments, financing, and facilities initiatives.	
Virginia	8.6		39 %	50,010	4	61	2	• Virginia provides economic incentives to bio-solution organizations such as tax credits and funding	
California	39.5		34 %	44,410	5	95	86	• California are involved in a partnership with the mission to strengthen the life science ecosystem and they provide tax credits • The regulatory conditions (e.g., on GMO and organic) are more strict than other states. However, they are encouraging technology by providing incentives, which is reflected by many alternative proteins manufacturers located there.	
Illinois	12.8		35 %	46,481	6	58	13	• The state of Illinois is invested in the life science sector	
Maryland	6.2		40 %	52,000	7	76	1	• Maryland have good conditions for bio-solution startups as they have available capital dedicated to the life science sector and have economic incentives to investors	
Washington	7.7		36 %	48,137	8	93	4	• No information has been found on underlying incentives and regulation in this state	
Pennsylvania	13.0		31 %	44,220	9	58	1	• The state of Pennsylvania is invested in the life science sector	
Colorado	5.8		41 %	45,030	10	72	12	• Colorado provides economic incentives to bio-solution organization through tax credits and funding	
Minnesota	5.7		36 %	50,000	11	64	2	• No information has been found on underlying incentives and regulation in this state	
Texas	29.1		30 %	40,075	12	94	10	• Texas has a labelling law restricting alternative proteins producers to market their product as meat	
Connecticut	3.6		39 %	50,015	13	61	2	• Connecticut provides economic incentives to bio-solution organization through tax credits and funding	
Michigan	10.1		29 %	44,606	14	95	2	• Michigan provides funding to bio-solution organization in early R&D phases	
Florida	21.5		30 %	40,000	15	58	6	• Florida provides funding to bio-solution organization in early R&D phases	

Degree of political support and focus for bio-solutions
 Low High

Overall attractiveness in relation to bio-solutions
 Low High

Note: * Bachelor degree or higher, ** Weighted average of population (50%), share high education (25%) and median income (25%); Source: USDA, United States Census Bureau, GFI, DQYD1, Biotechnology industry Organization, Bloomberg



Table 8: Attractive states – Enzymes for plant proteins and alternative proteins via fermentation (2/3)

State	Pop. 2020 (millions)	Pop. growth	Share w/ high. education*	Median income (USD)	Weighted rating**	State innovation index	# of alt. protein manufactures	Incentives & regulation	Attractiveness
North Carolina	10.4	↗	31	40,125	16	76	7	• North Carolina provides funding to bio-solution organization in early R&D phases	◐
Ohio	11.8	→	28	41,828	17	93	4	• The state of Ohio is invested in the life science sector	◐
Georgia	10.7	↗	31	39,524	18	58	2	• No information has been found on underlying incentives and regulation in this state	◐
Wisconsin	5.9	→	30	43,020	19	48	5	• Wisconsin have good conditions for bio-solution startups as they have available capital dedicated to the life science sector and have many economic incentives to investors	◐
Indiana	6.8	↗	27	43,041	20	41	N/A	• Indiana is involved in a partnership with the mission to strengthen the life science ecosystem and they provide tax credits and funding	◐
New Hampshire	1.4	↗	37	48,226	21	71	1	• No information has been found on underlying incentives and regulation in this state	◐
Oregon	4.2	↗	34	41,602	22	76	12	• No information has been found on underlying incentives and regulation in this state	◐
Arizona	7.2	↗	30	39,501	23	59	2	• Arizona provides economic incentives to bio-solution organization through tax credits	◐
Utah	3.3	↗	34	40,606	24	65	1	• Utah provides economic incentives to bio-solution organization through tax credits	◐
Missouri	6.2	→	29	40,050	25	38	4	• Missouri has a labelling law restricting alternative proteins producers to market their product as meat. They also provide tax credits to bio-solution organizations	◐
South Carolina	5.1	↗	28	42,000	26	31	N/A	• South Carolina provides funding to bio-solution organization in early R&D phases	◐
Rhode Island	1.1	↗	34	48,000	27	60	2	• Rhode Island is invested in the life science sector and provides tax credits to them	◐
Hawaii	1.5	↗	33	45,055	28	36	N/A	• Hawaii provides funding to bio-solution organization in early R&D phases	◐
Tennessee	6.9	↗	27	40,000	29	33	1	• Tennessee provides funding to bio-solution organization in early R&D phases	◐
Vermont	0.6	→	38	47,000	30	49	2	• No information has been found on underlying incentives and regulation in this state	◐
Nebraska	2.0	↗	32	43,010	31	32	1	• Nebraska have good conditions for bio-solution startups as they have available capital dedicated to the life science sector and have many economic incentives to investors	◐
Kansas	2.9	→	33	41,080	32	39	1	• Kansas is invested in the life science sector and provides economic incentives	◐



Note: * Bachelor degree or higher, ** Weighted average of population (50%), share high education (25%) and median income (25%); Source: USDA, United States Census Bureau, GFI, DQYDJ, Biotechnology Industry Organization, Bloomberg



Table 9: Attractive states – Enzymes for plant proteins and alternative proteins via fermentation (3/3)

State	Pop. 2020 (millions)	Pop. growth	Share w/ high. education*	Median income (USD)	Weighted rating**	State innovation index	# of alt. protein manufactures	Incentives & regulation	Attractiveness
Alabama	5.0		26	41.000	33	29	N/A	• No information has been found on underlying incentives and regulation in this state	
Nevada	3.1		25	43.900	34	33	1	• No information has been found on underlying incentives and regulation in this state	
Maine	1.4		32	42.551	35	32	1	• No information has been found on underlying incentives and regulation in this state	
Oklahoma	4.0		26	40.400	36	28	N/A	• Oklahoma is invested in the life science sector and provides economic incentives	
North Dakota	0.8		30	45.503	37	26	N/A	• No information has been found on underlying incentives and regulation in this state	
Iowa	3.2		29	40.020	38	40	2	• Iowa provides funding to bio-solution organization in early R&D phases	
Kentucky	4.5		24	40.026	39	25	1	• The state of Kentucky is invested in the life science sector and provides funding to them	
Idaho	1.8		28	42.102	40	48	N/A	• No information has been found on underlying incentives and regulation in this state	
Louisiana	4.7		24	40.000	41	19	N/A	• Louisiana has a labelling law restricting alternative proteins producers to market their product as meat	
Delaware	1.0		32	40.402	42	71	N/A	• Delaware is invested in the life science sector and provides funding to them	
Alaska	0.7		30	42.606	43	52	N/A	• No information has been found on underlying incentives and regulation in this state	
Montana	1.1		32	39.000	44	27	1	• Montana provides funding to bio-solution organization in early R&D phases	
Arkansas	3.0		23	40.000	45	15	N/A	• Arkansas has a labelling law restricting alternative proteins producers to market their product as meat	
New Mexico	2.1		27	36.000	46	64	N/A	• New Mexico is involved in a partnership with the mission to strengthen the life science ecosystem, and they provide tax credits and have funding	
South Dakota	0.9		29	40.001	47	27	N/A	• South Dakota has a labelling law restricting alternative proteins producers to market their product as meat. They also provide tax credits to bio-solution organizations	
Mississippi	3.0		22	32.763	48	6	N/A	• Mississippi has a labelling law restricting alternative proteins producers to market their product as meat	
Wyoming	0.6		27	42.100	49	43	N/A	• No information has been found on underlying incentives and regulation in this state	
West Virginia	1.8		21	38.000	50	10	1	• West Virginia provides funding to bio-solution organization in early R&D phases	

Degree of political support and focus for bio-solutions
 Low High

Overall attractiveness in relation to bio-solutions
 Low High

Note: * Bachelor degree or higher, ** Weighted average of population (50%), share high education (25%) and median income (25%); Source: USDA, United States Census Bureau, GFI, DQYDJ, Biotechnology Industry Organization, Bloomberg



Table 10: Attractive states –Digestive enzymes and probiotics for animal feed (1/3)

State	Cattle stock (millions)	State Innovation Index	Top 10 Agricultural University	Incentives & regulation	Attractiveness
Texas	10.9	61	Texas A&M University	 <ul style="list-style-type: none"> • Texas has a labelling law restricting alternative proteins producers to market their product as meat 	
Nebraska	6.2	32		 <ul style="list-style-type: none"> • Nebraska have good conditions for bio-solution start-ups as they have available capital dedicated to the life science sector and have many economic incentives to investors 	
Kansas	5.8	39		 <ul style="list-style-type: none"> • Kansas is invested in the life science sector and provides economic incentives 	
California	5.3	95	<ul style="list-style-type: none"> • University of California, Davis • California Polytechnic State University 	 <ul style="list-style-type: none"> • California are involved in a partnership with the mission to strengthen the life science ecosystem and they provide tax credits • The regulatory conditions (e.g., on GMO and organic) are more strict than other states. However, they are encouraging technology by providing incentives, which is reflected by many alternative proteins manufacturers located there 	
Oklahoma	4.3	28		 <ul style="list-style-type: none"> • Oklahoma is invested in the life science sector and provides economic incentives 	
Missouri	3.8	38		 <ul style="list-style-type: none"> • Missouri has a labelling law restricting alternative proteins producers to market their product as meat. They also provide tax credits to bio-solution organizations 	
Iowa	3.7	40	Iowa State University	 <ul style="list-style-type: none"> • Iowa provides funding to bio-solution organization in early R&D phases 	
South Dakota	3.7	27		 <ul style="list-style-type: none"> • South Dakota has a labelling law restricting alternative proteins producers to market their product as meat. They also provide tax credits to bio-solution organizations 	
Wisconsin	3.4	48		 <ul style="list-style-type: none"> • Wisconsin have good conditions for bio-solution start-ups as they have available capital dedicated to the life science sector and have many economic incentives to investors 	
Montana	2.6	27		 <ul style="list-style-type: none"> • Montana provides funding to bio-solution organization in early R&D phases 	
Colorado	2.5	71		 <ul style="list-style-type: none"> • Colorado provides economic incentives to bio-solution organization through tax credits and funding 	
Minnesota	2.3	67		 <ul style="list-style-type: none"> • No information has been found on underlying incentives and regulation in this state 	
Idaho	2.2	48		 <ul style="list-style-type: none"> • No information has been found on underlying incentives and regulation in this state 	
Kentucky	2.1	25		 <ul style="list-style-type: none"> • The state of Kentucky is invested in the life science sector and provides funding to them 	
North Dakota	1.8	26		 <ul style="list-style-type: none"> • No information has been found on underlying incentives and regulation in this state 	



Source: USDA, United States Census Bureau, GFI, DQYDJ, Biotechnology industry Organization, Bloomberg



Table 11: Attractive states – Digestive enzymes and probiotics for animal feed (2/3)

State	Cattle stock (millions)	State Innovation Index	Top 10 Agricultural University	Incentives & regulation	Attractiveness
Tennessee	1.8	33		<ul style="list-style-type: none"> Tennessee provides funding to bio-solution organization in early R&D phases 	
Arkansas	1.7	15		<ul style="list-style-type: none"> Arkansas has a labelling law restricting alternative proteins producers to market their product as meat 	
Florida	1.6	31	University of Florida	<ul style="list-style-type: none"> Florida provides funding to bio-solution organization in early R&D phases 	
Pennsylvania	1.6	58		<ul style="list-style-type: none"> The state of Pennsylvania is invested in the life science sector 	
Virginia	1.5	61		<ul style="list-style-type: none"> Virginia provides economic incentives to bio-solution organizations such as tax credits and funding 	
New York	1.5	64	Cornell University	<ul style="list-style-type: none"> New York has introduced the LifeSci NYC initiative to spur company creation and training and jobs placement 	
New Mexico	1.3	64		<ul style="list-style-type: none"> New Mexico is involved in a partnership with the mission to strengthen the life science ecosystem, and they provide tax credits and have funding 	
Oregon	1.3	76		<ul style="list-style-type: none"> No information has been found on underlying incentives and regulation in this state 	
Wyoming	1.3	44		<ul style="list-style-type: none"> No information has been found on underlying incentives and regulation in this state 	
Ohio	1.3	47	Ohio State University	<ul style="list-style-type: none"> The state of Ohio is invested in the life science sector 	
Alabama	1.2	29		<ul style="list-style-type: none"> No information has been found on underlying incentives and regulation in this state 	
Illinois	1.1	58	University of Illinois	<ul style="list-style-type: none"> The state of Illinois is invested in the life science sector 	
Michigan	1.1	61		<ul style="list-style-type: none"> Michigan provides funding to bio-solution organization in early R&D phases 	
Washington	1.1	93		<ul style="list-style-type: none"> No information has been found on underlying incentives and regulation in this state 	
Georgia	1.0	47		<ul style="list-style-type: none"> No information has been found on underlying incentives and regulation in this state 	
Mississippi	0.9	6		<ul style="list-style-type: none"> Mississippi has a labelling law restricting alternative proteins producers to market their product as meat 	
Arizona	0.9	59		<ul style="list-style-type: none"> Arizona provides economic incentives to bio-solution organization through tax credits 	



Source: USDA, United States Census Bureau, GFI, DQYDJ, Biotechnology industry Organization, Bloomberg



Table 12: Attractive states – Digestive enzymes and probiotics for animal feed (3/3)

State	Cattle stock (millions)	State Innovation Index	Top 10 Agricultural University	Incentives & regulation	Attractiveness
Indiana	0.9	41	Purdue University	<ul style="list-style-type: none"> Indiana is involved in a partnership with the mission to strengthen the life science ecosystem and they provide tax credits and funding 	
North Carolina	0.8	60	North Carolina State University	<ul style="list-style-type: none"> North Carolina provides funding to bio-solution organization in early R&D phases 	
Utah	0.8	65		<ul style="list-style-type: none"> Utah provides economic incentives to bio-solution organization through tax credits 	
Louisiana	0.8	19		<ul style="list-style-type: none"> Louisiana has a labelling law restricting alternative proteins producers to market their product as meat 	
Nevada	0.5	33		<ul style="list-style-type: none"> No information has been found on underlying incentives and regulation in this state 	
West Virginia	0.4	10		<ul style="list-style-type: none"> West Virginia provides funding to bio-solution organization in early R&D phases 	
South Carolina	0.4	31		<ul style="list-style-type: none"> South Carolina provides funding to bio-solution organization in early R&D phases 	
Vermont	0.3	49		<ul style="list-style-type: none"> No information has been found on underlying incentives and regulation in this state 	
Maryland	0.2	76		<ul style="list-style-type: none"> Maryland have good conditions for bio-solution start-ups as they have available capital dedicated to the life science sector and have economic incentives to investors 	
Hawaii	0.1	36		<ul style="list-style-type: none"> Hawaii provides funding to bio-solution organization in early R&D phases 	
Maine	0.1	32		<ul style="list-style-type: none"> No information has been found on underlying incentives and regulation in this state 	
Connecticut	0.0	82		<ul style="list-style-type: none"> Connecticut provides economic incentives to bio-solution organization through tax credits and funding 	
Massachusetts	0.0	94		<ul style="list-style-type: none"> The state of Massachusetts has passed several projects and incentives to accommodate bio-solution organizations. This includes investments, financing, and facilities initiatives. 	
New Hampshire	0.0	71		<ul style="list-style-type: none"> No information has been found on underlying incentives and regulation in this state 	
New Jersey	0.0	72		<ul style="list-style-type: none"> Incentives to bioscience investors (state tax credits); Provide state investments in bioscience companies through funds of funds 	
Delaware	0.0	71		<ul style="list-style-type: none"> Delaware is invested in the life science sector and provides funding to them 	
Alaska	0.0	52		<ul style="list-style-type: none"> No information has been found on underlying incentives and regulation in this state 	
Rhode Island	0.0	60		<ul style="list-style-type: none"> Rhode Island is invested in the life science sector and provides tax credits to them 	



Source: USDA, United States Census Bureau, GFI, DQYDJ, Biotechnology Industry Organization, Bloomberg

6.3 Key opportunity spaces

When assessing the different opportunity spaces, it is important to evaluate them based on a number of strategic considerations that need to be met for the opportunities to be relevant and attractive for a broad specter of Danish bio-solutions providers.

These considerations relate to market presence, size, growth potential, urgency for bio-solutions to unlock the untapped potential, attractive timeframe, and supportive conditions that together make the opportunities realistic and achievable. More specifically:

- Opportunities need to represent a **large and untapped market potential**, meaning that while the market is associated with potentially high value and growth potential, the realization of this potential is currently blocked by some significant issues that need to be overcome first.
- Untapping the market potential should **require the application of innovative technology**.
- Materialization of the market potential is considered **realistic within the short to medium term**, i.e., presence of basic conditions such as existing demand, technology maturity, etc. are either already in place or expected to within the near future.
- Opportunities need to be **located within a supportive environment**, i.e., for example geographically close to the clients, encouraging regulative conditions, close to knowledge and competence centers, workforce, and other capabilities needed to maximize the chance of success.

Based on these considerations, Ramboll has identified **three key opportunity spaces**:

- 1) Deployment of enzymes as ingredients to plant-based meat in California
- 2) Deployment of enzymes as ingredients to plant-based dairy in California
- 3) Deployment of enzymes to optimize feed efficiency for cattle/beef in California

All of these opportunities are associated with a potentially large and still relatively untapped market potential that can possibly be unlocked with the help of bio-solutions. In particular, enzymes used to improve the functionality of plant-based proteins are considered promising, as this technology is already readily available and quickly maturing, possibly enabling to unlock the market potential already within the short run.

Although other states could also be considered relevant, e.g., New York, Illinois, Midwest states, etc., the center of gravity for bio-solutions is assessed to be in **California**, and especially within the area of San Francisco Bay. Despite its relatively strict regulation on health claims compared to some other states, it is a highly attractive market with strong purchasing power, demand for innovative and green solutions, heavy R&D focus, and a strong presence of B2B companies that are relevant client segments for enzymes. It is also a large agricultural area focused on cattle holdings. These advantageous conditions outweigh the somehow stricter regulation (mainly on the health claims) than is the case in some other states.

Overview and reasoning for the selection of the three selected opportunity spaces are presented in the table below.

Table 13: Key opportunity spaces

Criteria	1) Enzymes as ingredients to plant-based meat in California	2) Enzymes as ingredients to plant-based dairy in California	3) Enzymes to optimize feed efficiency for cattle/beef in California
Opportunity summary	<p>While the market potential is expected to be high, there are still some major challenges that need to be addressed and overcome including parity on taste, texture, and price.</p> <p>However, the technology that can help improve the functionality of plant-based proteins is already existent, commercialized, and quickly advancing. Furthermore, based on the case of plant-based milk, there is a strong indication that the meat consumers are ready for the transition towards a more flexible diet including greener alternatives, as soon as parity issues are resolved.</p> <p>Plant-based meat alternatives are expected to gain a ~15% market share in the meat sector in 2035 (compared to ~ 1% now), corresponding to a market size of \$ 17 billion.</p> <p>The highest opportunity within the feasible timeframe is assessed in regard to enzymes used to improve the functionality of plant-based proteins. More advanced solutions, such as obtaining alternative proteins directly through fermentation (e.g. precision fermentation) are more forward-looking while unlocking the potential via additive enzymes is already realizable within the short term.</p> <p>California is assessed to be the state with the greatest opportunities within enzymes for plant-based proteins due to its overall supportive environment (regulatory, proximity to knowledge, clients, partners, etc.).</p>	<p>Whereas some types of alternative dairy products, e.g. milk, are already doing quite well, others like yogurt, cheese, etc. are lagging behind. This is to a large degree driven by the fact that buyers of the plant-based milk accept that the product is not 100% identical to the animal-based milk, while this is a bigger change e.g. in the case of cheese, due to issues with the required functionality (e.g. texture and stretchability).</p> <p>The estimated market potential of plant-based dairy alternatives is similar to that of plant-based meat (~16bn USD in 2035), but it is expected to grow at a slightly lower rate between 2020 and 2035, due to a higher starting point.</p> <p>As in the case of plant-based meat alternatives, parity problems are expected to be solved by enzymes within the short to medium term, while alternative proteins via fermentation is a very promising but more long-term solution.</p> <p>California is expected to be the state offering the most attractive environment (regulation, proximity to knowledge, clients, partners, etc.).</p>	<p>The increasing demand for animal-based proteins and the rising livestock population are among the key drivers of the growing feed consumption in the U.S. Furthermore, the increased preference for natural products encourages the farmers to cut chemicals and rely on bio-solutions in the feed to optimize operating costs.</p> <p>While the use of enzymes to optimize feed is already common in the case of e.g. poultry, cattle farmers are first now beginning to learn about the benefits of using enzymes and probiotics in cattle holdings. As the technology is already relatively mature and still advancing, there is assessed a great potential within this sector – both related to catching up on the untapped market potential, but also due to the continuously growing livestock population and feed demand.</p> <p>Despite this category being focused on enzymes to optimize feed efficiency, similar conclusions are expected for probiotics, since these two products are in many cases considered complementary. I.e., farmers who adopt one of these products are likely to be open to the other one as well.</p> <p>Also here, California is assessed to be the most attractive state as a potential starting point, due to favorable regulatory conditions, access to technology, knowledge, workforce, etc., as well as the large cattle holdings (California is the 4th largest cattle state in the U.S.).</p>
Market potential	<p>The U.S. plant-based meat market was estimated at 1.6 billion USD in 2020 (~1% of the total U.S. meat market), and it is expected to reach 17 billion USD by 2035 (~15% of the total U.S. meat market). Although the current market share of plant-based meat</p>	<p>The U.S. plant-based dairy market was estimated at 4.4 billion USD in 2020 (~6% of the total U.S. dairy market), and it is expected to reach 16 billion USD by 2035 (~20% of the total U.S. meat market). The growth</p>	<p>Today, cattle livestock is the largest consumer of feed in the U.S., with expected consumption growth of ~45% in 2035 (reaching 168 million tons of feed consumed).</p>

	<p>alternatives is still very low, it is expected to increase significantly driven by consumers seeking alternative proteins to balance their diet with.</p> <p>Although the alternative proteins are currently still challenged within the meat market by parity issues (taste, texture, and price not meeting expectations), unlocking the market potential is expected to be possible already within the short to medium term, given the existing technology advancement within enzyme additives.</p> <p>The highest potential within the relevant timeframe is assessed with regards to enzymes (as additives to improve the parity of plant proteins). While using fermentation to obtain alternative proteins directly offers huge potential with regards to solving the parity issues, this technology is not expected to be suitable for the industrial-scale within the next 5 years, due to high-price and other challenges – e.g. shortage of suitable contract manufacturing facilities.</p>	<p>will be particularly prominent during the next 5 years, as it is easier to adopt than e.g. plant-based meat. Plant-based dairy is in many cases used as a meal ingredient, and not as a key meal element meaning that the parity issues can in some cases be less significant.</p> <p>Also here, the highest potential within the relevant timeframe is assessed with regards to enzymes as additives to improve the parity of plant proteins.</p>	<p>Previously, cattle have been an unexplored market of digestive enzymes for animal feed, due to the ambiguity of its effect. However, as there have been found scientific evidence proving the benefits of the enzymes for cattle, and the restriction on the use of antibiotics, a large and fairly untapped market has emerged.</p> <p>In the short term, the enzyme market is expected to experience large growth rates throughout the pursuit of reaching the same market penetration of poultry. Thereafter, the market is expected to grow in line with the cattle feed consumption.</p>
<p>Time perspective</p>	<p>Short to medium term – The technology is already existing and maturing quickly to decrease the parity gaps. Furthermore, the demand is maturing quickly as well, meaning that the market potential can be unlocked already in the short to medium run.</p>	<p>Short term – The technology is already existing and maturing, and the need is urgent as farmers are experiencing higher prices for feed inputs. Moreover, the poultry category is already mature, why it is expected that the cattle category quickly can catch up as farmers are becoming aware of the cost and sustainability benefits of using enzymes exists for cattle as well.</p>	
<p>Supportive environment</p>	<p>California is assessed to be the state with the greatest opportunities for bio-solutions within food, due to its overall supportive environment. California is by far the state with the largest concentration of alternative protein manufacturers. Currently, there are 86 manufacturers located in California, creating a large market of enzymes for alternative proteins. This is closely connected to a large population with the traits of a typical alternative protein consumer, but also a general demand for innovative and green solutions. Furthermore, California is a hub for life science knowledge, which is supported by favorable state incentives directed at new technology and bio-solutions.</p> <p>On the other side, since California is the state with the fastest technology adaption they are the most regulatory progressed state, resulting in relatively strict regulations on health claims compared to other states. E.g., they have strict definitions of organic and GMO products. However, entering the market will require resources and in most cases collaboration and support on the regulatory process regardless of which state is selected as the starting point. Therefore, being attractive in all other important areas (e.g. open to innovation, proximity to B2B clients and knowledge centers, etc.) is considered to offset the strict regulatory conditions.</p>	<p>California is assessed to be the state with the greatest opportunities within digestive enzymes and probiotics for animal feed due to its overall supportive environment. In addition to the favorable incentive conditions, California is the 4th largest cattle state in the U.S. Furthermore, California has two of the greatest universities within agriculture allowing having partnerships and collaborations with some of the leading experts within the area. In addition, a qualified workforce will be available as they graduate from the universities.</p>	

While other interesting opportunity spaces were considered, all of them have some limitations associated with the strategic considerations described above.

- Manufacturing [alternative proteins directly via fermentation](#) is a highly promising technology since proteins derived this way are very similar to those obtained from animals, which can instantly solve the taste and texture parity issues. However, although the technology already exists, it is not yet feasible at an industrial scale, and it is not expected to be fully competitive with plant-based proteins within the short run.
- [Plant-based alternatives to eggs](#) are also considered an attractive opportunity space, as it is an upcoming market that is expected to exhibit high growth rates through 2035. However, mimicking egg proteins, both with regards to taste and functionality has not been widely successful yet. Therefore the potential in this market is first expected to be unlocked by the more innovative solutions, like precision fermentation.
- [Enzymes to optimize the efficiency of poultry feed](#) were also identified as a possible opportunity space, due to the high expected growth in the demand for poultry-based proteins in the U.S. However, it is already a relatively mature market with possibly high competition. Hence, the need for innovation in this market is potentially less urgent than e.g. within the cattle market.
- While targeting the feed optimization market, other large livestock states, such as the [Midwest states and Texas](#), could also make potential opportunity spaces. Most of these states have agricultural knowledge centers and strong agricultural industry associations driving the political agenda (as the state economy relies on the agricultural industry). However, most of these states also encourage meat production by blocking opportunities for plant-based alternatives. Thus, even though a large potential exists in these states, they are not an optimal starting point for the promotion of bio-solutions across sectors. On the other hand, California is encouraging both the plant-based industry and agricultural industry.

7. KEY STAKEHOLDERS AND POTENTIAL COLLABORATIONS

This chapter aims to identify and assess key stakeholders that need to be managed both from the perspective of the Danish bio-solution providers that want to enter the US market and from the perspective of DMFA who want to initiate and kick-start a potential cross-border collaboration between the Danish and the US stakeholders.

7.1 Key stakeholders from perspective of DK bio-solution providers

In the previous chapter, we have identified three key opportunities within the U.S. bio-solution sphere including deployment of enzymes as ingredients to plant-based meat, dairy, and optimizing feed efficiency for cattle/beef. California was identified as the most attractive location for pursuing these opportunities. In this chapter, we [identify and assess potential key stakeholders, with direct relevance to these opportunities](#).

In addition to potential clients, competitors, and regulatory agencies that need to be dealt with, there is a number of various stakeholders that can potentially play an important role in enabling and enhancing the introduction of the above-mentioned technologies to the U.S. market (with the starting point in California). These include supporting organizations, such as technology and knowledge hubs, research institutions, NGOs, etc. that can be helpful with regards to further innovation/technology sparring, promotion of bio-solutions in the U.S. market, lobbying for more supportive/favorable regulatory framework conditions at both the federal and state level, and finding potential collaboration partners, contractors, etc.

Although it might be in general considered easier to introduce new bio-solution to the U.S. than e.g. to the EU, it will in most cases require significant resources. New entrants will need promotion (both commercially and politically), distribution network, knowledge of the U.S. regulatory system, etc., which in most cases will take a long time and be too expensive to build up on their own. While acquiring those capabilities is not an option for most of the bio-solution providers, collaboration and partnerships with larger and well-established market players can be a solution. These companies can either be clients (both the traditional food production giants seeking to expand their offering or producers of plant-based products) but also competitors, all seeking partnerships to source attractive technologies that can help position themselves within the alternative protein market but are too risky or too expensive to acquire or develop themselves. They can also be large distributors that seek to include bio-solutions within their product portfolio, e.g. digestive enhancers sold in animal health shops. In return for innovation, these companies can offer access to administrative support (e.g. regulatory applications), sales channels, distribution networks, production capacity, etc.

Collaborating with large animal-based protein producers (especially meat, dairy, etc.) is also an effective way for the bio-solutions producers to position themselves within the value chain as a complementary solution to the animal-based proteins, instead of trying to replace them. Some experts believe that this could be the most effective way to minimize the resistance from animal-based protein producers and agricultural organizations, and ultimately it could result in a higher acceptance of plant-based products. Especially given the fact that a full phase-out of animal proteins is not a likely scenario in the U.S. within the foreseeable future.

Based on the interviews with the various market players, it became evident that collaborations are also common amongst competitors, mostly with the purpose to drive innovation and to gain critical mass needed to push the market toward higher acceptance of alternative proteins (e.g. via lobby activities). Such collaborations can include companies of similar size (e.g. medium-sized) but also smaller companies bringing innovation to the larger ones, in return getting access to sales channels, resourced for regulatory approvals, etc.

Another key challenge that many of the smaller bio-solution providers in the U.S. face is the limited manufacturing capacity, that lives up to their production requirements and needs. While there is a number of start-ups backed up by investments and interested in up-scaling, growing, etc., the available manufacturing capacity is at a premium. The available capacity in the U.S. is mainly at the contract and mostly for pilot-scale operations. Furthermore, it is often not fit for purpose, and the pharmaceutical infrastructure is too complex and expensive for most of the enzyme producers. Finding and securing production capacity should therefore be a priority, either on their own or in collaboration with stronger market players. Identified key stakeholders, many of whom could potentially become partners, are described in Table 14 below.

Table 14: Overview of the key stakeholders

Note that the list is not exhaustive, but in our opinion, it gives a good indication of what kind of stakeholders should be considered for collaboration (also across the U.S.). Furthermore, most of these organizations would also be relevant for other types of bio-solutions and potentially off-taker markets.

 Enzymes as ingredients to plant-based meat in California
  Enzymes as ingredients to plant-based dairy in California
  Enzymes to optimize feed efficiency for cattle/beef in California

Stakeholder category	Opportunity association	Stakeholder	Brief description	Role in relation to bio-solution providers
Regulatory body		The FDA	The FDA is the main regulatory agency for bio-solutions at the federal level. It is the primary agency running the approval processes for new bio-solutions.	Regulator; Guidance The bio-solutions manufacturers have to comply with FDA’s legislation. However, the FDA has also committed to providing direct support and involvement from the FDA’s Commissioner and senior agency leaders, to engage with our stakeholders on innovations in plant and animal biotechnology ⁹⁷ .
		The USDA	The USDA is a secondary regulatory agency for bio-solutions at the federal level. It is the primary agency running the regulation on protein labeling and ensuring a safe meat supply.	Regulator The bio-solutions manufacturers have to comply with USDA’s legislation.
		Agricultural Research Service	USDA department: In collaboration with scientists and postdocs, they run 600+ research projects to deliver scientific solutions to national and global agricultural challenges.	Regulator; Guidance; Financial support Has mandates directed at helping the U.S. food and agriculture businesses, which is supported through a national grant program outside the USDA.
		National Institute of Food and Agriculture	USDA department: Provides leadership and funding for programs that advance agriculture-related sciences. Invests in and supports initiatives that ensure the long-term viability of agriculture.	Regulator; Guidance; Financial support Has mandates directed at helping U.S. agriculture businesses by offering funding to research programs.
		California State Assembly, Committee on Biotechnology	The primary state government institution on biotechnology: Tasked with being the biotechnology industry’s voice to Californian state lawmakers. Their goal is to ensure that California remains a	Political partner; Promoter Engages in discussions and hearings with various bio-solution providers to gain a better un-

⁹⁷ The FDA: Plant and Animal Biotechnology Innovation Action Plan

			leader in biotechnology, high technology, clean technology, and life sciences.	derstanding of the market, and to lay a foundation for creating sound policies that help the innovation economy flourish. Acts as the link between the state legislation and the biotechnology industry.
Supporting organizations (industry associations, lobby organizations, NGOs, etc.)		Good Food Institute	An international NGO with the aim to promote alternative proteins as the default choice. Active in driving the modernization of the biotechnology regulation pathway and supporting research within alternative proteins.	Guidance; Collaboration enhancer; Promoter; Lobby partner Identify the most effective solutions, mobilize resources and talent, and empower partners across the food system to make alternative proteins accessible, affordable, and delicious.
		Biotechnology Innovation Organization	The world’s largest advocacy association representing member companies, state biotechnology groups, academic and research institutions, and related organizations across the United States and in 30+ other countries.	Guidance; Collaboration enhancer; Promoter Gather most of the bio-solution industry including bio-solution providers, agricultural companies, corn-growers, etc. representing various interests across these segments.
		Environmental Defense Fund	A world-leading environmental organization with one of the most influential nonprofit boards in the U.S. Has been a pioneer in using science and different perspectives to make the environment safer and healthier. The California office is located in Sacramento.	Guidance; Collaboration enhancer; Promoter Drive large transformations within sustainable agricultural systems making them highly relevant for digestive enzymes and probiotics providers.
		The Biological Products Industry Alliance	The BPIA is advancing sustainability through biological solutions, dedicated to fostering continued improvements to the biological products regulatory process. Their primary domain area is within the agricultural sector where they explicitly mention California as a state of relevance.	Guidance; Collaboration enhancer; Promoter Despite limited presence within the feed area, they have the important stakeholders for digestive feed enzymes and probiotics as members. Hence, being in a partnership with them allows the bio-solutions providers to get access to potential clients.
		The Plant-Based Foods Association	The association was founded in 2016 to act as a collective voice for its 185+ company members. It is located in San Francisco.	Guidance; Political/lobby partner; Collaboration enhancer; Promoter Help providers of enzymes for plant-based dairy and meat to lobby for policy and labeling regulations, research & education funding, marketplace development, and putting plant-based foods on the map through their public appearance.

	<p>California Plant-Based Alliance</p>	<p>A Plant-based industry alliance helps ensure that California businesses will be leading the way to meet the demand of the plant-based industry.</p>	<p>Guidance; Political/lobby partner; Collaboration enhancer; Promoter</p> <p>Lobbying for legislation with a significantly positive impact on the plant-based industry. They encourage cooperation with affiliate organizations, like bio-solutions, to foster growth, development, and success.</p>
	<p>California Grain & Feed Association</p>	<p>A non-profit collaborative organization seeking to provide government advocacy, education, information, and activities that firms in the feed industry utilize to collectively address industry needs, interests, and issues continuously.</p>	<p>Guidance; Political/lobby partner; Promoter</p> <p>Has two registered lobbyists on staff and a technical director who play a key role in influencing decision-making in California on behalf of the industry. Hence, the association is both a potential partner for driving legislation within the feed area and a provider of the grain and feed network in California.</p>
	<p>Western United Dairies</p>	<p>A lobbying organization and think tank that represents nearly two-thirds of California's dairy farms.</p>	<p>Political/lobby partner; Promoter</p> <p>Lobbying for legislation on sustainable measures that potentially could have a significantly positive impact on the digestive enzymes and probiotics industry.</p>
	<p>Biocom California</p>	<p>Since 1995, Biocom California has helped move the life science industry forward with transformative resources that enable companies to make meaningful connections.</p>	<p>Guidance; Political/lobby partner; Collaboration enhancer; Promoter</p> <p>Biocom can act as a supporting partner within public policy & advocacy, building networks, capital development, business strategies & services, and workforce development. With 1,500 members, they connect companies enabling collaboration, capital investments, and innovation to enhance growth and efficiency.</p>
	<p>The North American Climate Smart Agriculture Alliance</p>	<p>A farmer-led platform for inspiring, educating, and equipping agricultural partners to innovate effective local adaptations that sustain productivity, enhance climate resilience, and contribute to the local and global goals for sustainable development.</p>	<p>Guidance; Collaboration enhancer; Promoter</p> <p>One of NASCAR's climate-smart agriculture strategies is to sustainably increase agricultural productivity and livelihoods (i.e. sustainable intensification).</p>

		California Cattle-men's Association	Non-profit trade association, formed in 1917, representing California's ranchers and beef producers in legislative and regulatory affairs.	Guidance; Political/lobby partner; Collaboration enhancer; Promoter Dedicated to positively influencing regulations and legislation of cattle operations in both California Sacramento and Washington, D.C. They could potentially be a promoter of bio-solutions within fees to its members.
		Bioscience Los Angeles County	Public-private agency with the mission to strengthen the life sciences ecosystem. It was established with support from Los Angeles County and 11 corporate sponsors.	Guidance; Political/lobby partner; Collaboration enhancer; Promoter Can support bio-solutions by assembling key players from the industry, accelerating startup activity, stimulating job growth, and attracting investment to the area.
Knowledge hubs		University of California, Berkeley	Ranks as one of the 10 best biotechnology universities in the world. They offer classes with distinguished professors contributing to the latest research within biotechnology.	Guidance; Innovation collaboration; Collaboration enhancer Has established the Alternative Meat Lab in collaboration with industry partners. This is a hub connecting students, entrepreneurs, venture capitalists, and industry leaders interested in creating the plant-based food of the future.
		University of California, Davis	Ranks as one of the 10 best agricultural universities in the world. Famous for its outstanding programs in the biological and agricultural sciences, offering classes with distinguished professors contributing to the latest research within agriculture.	Guidance; Innovation collaboration Can support innovation with subject matter expertise from the local market. In a similar way as the UC Berkley.
		Stanford University	Ranks as one of the 10 best biotechnology universities in the world. Offer classes with distinguished professors contributing to the latest research within biotechnology.	Guidance; Innovation collaboration Stanford University's Department of Biosciences can support innovation with subject matter expertise from the local market. In a similar way as the UC Berkley.
		University of California, San Diego	Ranks as one of the 10 best biotechnology universities in the world. In 2020, it ranked as the 4 th best university for Biomedical and Bioengineering in the U.S. Offer classes with distinguished professors contributing to the latest research within biotechnology.	Guidance; Innovation collaboration Stanford University's Department of Biosciences can support innovation with subject matter expertise from the local market. In a similar way as the UC Berkley.
		MISTA	California-based start-up optimizer focusing on the development of sustainable and innovative food by utilizing its well-connected platform.	Guidance; Innovation collaboration; Collaboration enhancer; Commercialization partner

				<p>Comprise companies such as Chr. Hansen, Givaudan, Danone, Ingredion, and Mars, to work with a selected cohort of around 20 start-up companies. The organization also collaborates with a range of service partners, venture financiers, and renowned universities such as UC Davis and UC Berkeley.</p>
		<p>KitchenTown</p>	<p>A California-based start-up incubator driving innovation in all its forms to support positive change in the food system from the ground up.</p>	<p>Guidance; Innovation collaboration; Collaboration enhancer; Commercialization partner</p> <p>The incubator is built around food entrepreneurs and innovators providing a supporting environment to startups and small-scale companies. They offer assistance in form of food experts, scientists, chefs, food engineers, and a small batch production facility. Bio-solutions providers could potentially tap into this ecosystem of knowledge, commercialization assistance, and potential clients in the startup phase.</p>
<p>Potential clients</p>		<p>Traditional food production giants seeking offer expansion</p>	<p>Seek innovations that can help them to stay competitive in the changing market (consumer preferences changing towards animal-free, healthy, and clean label foods, and the general climate agenda).</p> <p>OSI Group and Tyson Foods are examples of organizations within this category, which also have production plants in California.</p>	<p>Client; Competitor; Commercialization partner/enabler</p> <p>Can be both clients and competitors for enzymes and alternative proteins producers, i.e., often have their own R&D activities (incl. investments in bio-solution companies), but also buys enzymes, and other bio-solutions, especially when developing on their own is associated with large investments and high risks (e.g., patented technologies).</p>
		<p>Pure plant-based products producers</p>	<p>Producers of plant-based food specialized in more traditional and commercialized techniques (e.g., sausages, etc. based on plant proteins processed using enzymes, e.g., to improve taste). Moreover, the group consists of innovative companies that apply more novel techniques to produce plant-based food (both mimicking meats, etc. but also other alternatives).</p> <p>Examples of California-based plant-based meat producers: Beyond Meat, Impossible Foods, and Alpha Foods. Examples of California-based plant-</p>	<p>Client; Competitor; Commercialization partner/enabler</p> <p>Can be both clients and competitors, i.e., can either be the buyer of bio-solution and apply them in their products, or producers of competing solutions (in some cases with the potential to become customers).</p>

			<p>based dairy producers: Miyoko’s Creamery, Follow Your Heart, and Kite Hill.</p> <p>A broader overview of plant-based and fermentation-derived protein manufacturers in California is provided in Appendix.</p>	
		<p>Distributors</p>	<p>Legacy companies specialized within a specific area or with a strong geographical presence in a given location can partner up with a bio-solution provider (mostly enzymes) to distribute their products across the country.</p> <p>Brenntag is a California-based example of an organization within the category.</p>	<p>Client; Competitor; Commercialization partner/enabler</p> <p>Can be both clients and competitors, i.e., can buy the proteins and then sell them via own channels (e.g., to diversify portfolio), but will in many cases also sell competing products (e.g., synthetic alternatives).</p>
		<p>Large meat and dairy processors</p>	<p>Slaughterhouses/food processors purchase animals from the farmers.</p> <p>Examples are Golden West Food Group, Tyson Foods, Vander Eyk Dairy, Springville Beef, One World Meat Co., The Beef Boutique, Tara Firma Farms, Belcampo Meats, Farmdale Creamery, Leprino Foods, and California Dairies. They all have operations in California.</p>	<p>Clients</p> <p>Although the cattle industry is less vertically integrated than e.g. poultry, the slaughterhouses, and dairy processors will in many cases set requirements to the farmers they collaborate with. These requirements could comprise dietary mix, and hereunder also use of enzymes and probiotics. Collaboration with these companies and making them aware of the benefits associated with digestive enzymes and probiotics could result in them pushing the bio-solutions over to the farmers.</p>
		<p>Large farmers</p>	<p>Farmers with large cattle/dairy cows holdings.</p> <p>Examples are Harris Ranch, Maddox Dairy, Imperial Valley, Koopmann Ranch, Bear Valley Ranch, Joseph Farms, Rockview Farms, Alta Dena Dairy, and Dot Seven Ranch. They all have their operations in California.</p>	<p>Clients</p> <p>Use enzymes and probiotics as dietary supplements. Large farmers could be targeted directly and potentially educated in the benefits associated with digestive enzymes and probiotics.</p>

		<p>Feed producers</p>	<p>Although cattle feed is many cases produced locally, some of it can also be potentially produced far away and transported.</p> <p>Examples are Tyson Foods, Alltech, Land O’Lakes, Associated Feed, Foster Feed Yard, Verhoeven, Sun-Gro Commodities, and Grain Inc. The majority of these have operations in California.</p>	<p>Clients; Innovation collaboration</p> <p>Enzymes can be added directly to the feed, which is then distributed to the farmers locally or globally.</p>
<p>Competitors</p>		<p>Large bio-solution manufacturers</p>	<p>Large organizations that focus on manufacturing bio-solutions and have a footprint in the U.S (not limited to California).</p> <p>The category includes direct competitors such as BASF, DSM, IFF, Novozymes, and Chr. Hansen.</p> <p>An overview of bio-solution providers in California is provided in the Appendix.</p>	<p>Competitors; Innovation collaboration; Political/lobby partners; Commercialization partner/enabler</p> <p>Large competitors already established in the U.S. market and California can help the Danish bio-solutions providers target the Californian market via partnerships, in a similar manner as a partnership with large Clients. Furthermore, companies within the biotech sector can improve the general market condition by collaborating on e.g. political lobby, etc.</p>
<p>Contract manufacturers</p>		<p>Californian contract manufacturers</p>	<p>California-based organizations that provide contract manufacturing services. Some of the organizations also have their own production.</p> <p>The category includes organizations such as Avid Bioservices, Don Lee Farms, Initiative Foods, and Before the butcher (Uncut).</p> <p>An overview of contract manufacturers in California is provided in the Appendix.</p>	<p>Contract manufacturer; Guidance</p> <p>The organizations can help the bio-solutions providers with the manufacturing of their products.</p> <p>Some of the organizations have already focused their operations on plant-based technology, which makes them able to guide the bio-solution providers.</p>

7.2 Key stakeholders from perspective of DMFA

This section aims to map key stakeholders' groups for DMFA in connection with their work on promoting the cooperation within bio-solutions between Denmark and the US and determine how to approach them to kick-start the initiative. In addition to the US stakeholders mapped in the previous sections, DMFA will need to engage various companies and organizations in Denmark. These companies can be grouped into categories:

- **Danish bio-solution providers:** Various Danish bio-solution providers offering bio-solutions within the food and/or agricultural sectors, with an interest to enter the U.S. market.
- **Danish industry organizations (public and private):** Organizations working within and supporting the field of bio-solutions including associations with bio-solution providers as members. Examples are The Danish Chamber of Commerce (DE), The Confederation of Danish Industry (DI), Innovation Centre Denmark, Danish Agriculture & Food Council, the Danish Veterinary and Food Administration, and Food & Bio Cluster Denmark.

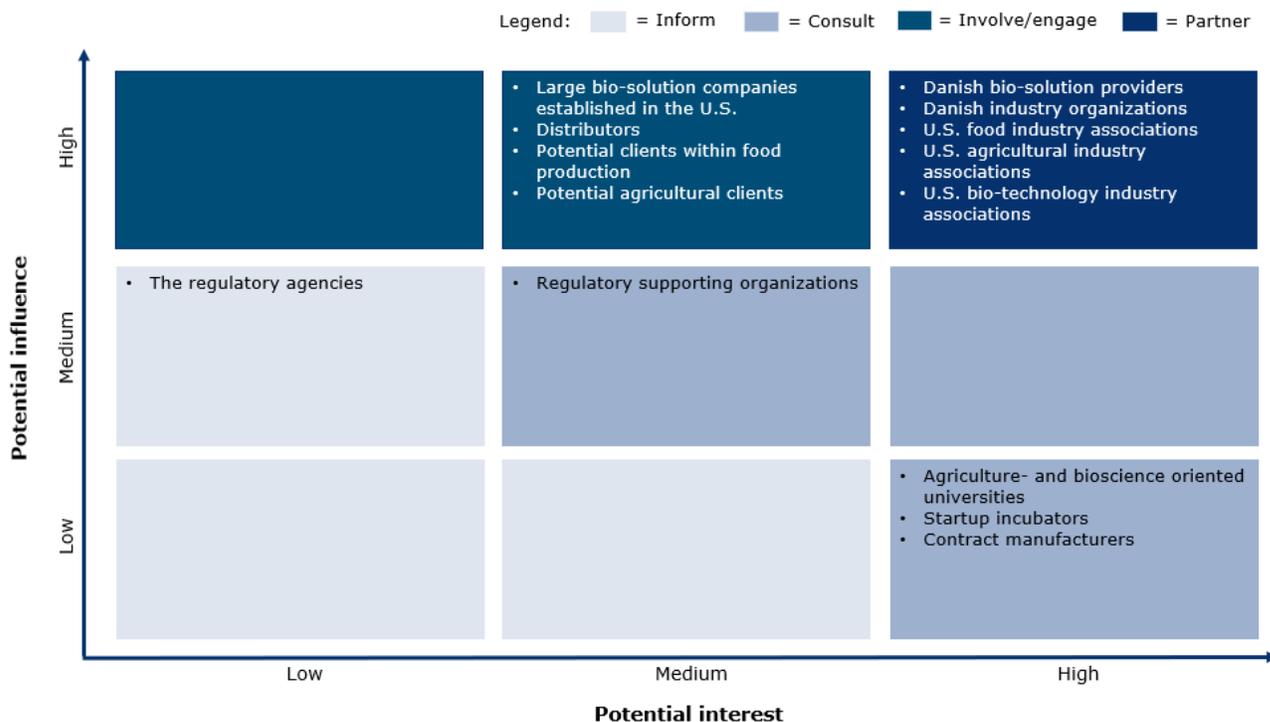
To better understand how to prioritize and approach each of these stakeholders, they have been mapped into an influence-interest matrix (Figure 12 below). The evaluation of the stakeholders' influence is based on both their position of authority (i.e., a formal position giving the capacity to make certain decisions or demands) and social power (i.e., being able to persuade others or having the right network) that can be used to either advance or block the project. The interest of the stakeholders is evaluated based on their curiosity and the relevance to their work.

Based on the level of potential influence and interest, the matrix classifies each stakeholder into different stakeholder management strategies. The stakeholder management strategies can be divided into four groups:

- **Keep informed:** Stakeholders with low/medium influence or interest fall within this category. They are typically characterized as stakeholders whose work is related to the field of bio-solutions. However, they do not have the means to impact the introduction of Danish bio-solutions into the U.S. market. Nor do they have a high interest to take part in the project. Thus, they should be monitored and kept informed on the key action points within the project.
- **Consult:** Stakeholders with medium/low influence and high/medium interest falls within this category. As these stakeholders both have potential influence and interest, it should be identified how each stakeholder can contribute, and they should be potentially consulted on these areas during the project.
- **Involve/engage:** Stakeholders with high influence and low/medium interest falls within this category. It is important to keep these stakeholders satisfied as they have the power to impact the project negatively. Thus, expectations should be aligned early on and determine how these stakeholders contribute to the project. However, as their interest is potentially limited, the involvement should be focused on only the most important matters.
- **Partner:** Stakeholders with high influence and interest fall within this category. These are the stakeholders that have the highest impact on the likelihood of the project succeeding. Thus, they should be closely managed, with their expectations identified and approached. Moreover, some of them could potentially act as partners in terms of driving the project.

Results of the stakeholder evaluation are presented in the table figure below. Based on this mapping the stakeholders identified as key (with potentially highest relevance for the initiative include) are the Danish bio-solution providers, U.S. industry organizations (e.g., Good Food Institute, California Grain & Feed Association, etc.), and Danish industry organizations (e.g., DE, DI, etc.). These stakeholders should be engaged early in the process and potentially involved as a partner. Stakeholders including different potential clients within the food and feed sector and the large bio-solution providers already established in the U.S. are also considered relevant for the initiative, however, due to their potentially limited interest/influence, their engagement should be focused on specific areas instead of a general involvement. The remaining stakeholders might be relevant for the project, but due to potentially a very limited interest and/or importance for the project, it is sufficient to inform them about the initiative, and engage only if/or assessed relevant.

Figure 12: Influence-interest mapping of DMFA stakeholders



Source: Ramboll

To operationalize this assessment further, we have assessed and described how to approach each of the stakeholders based on their position in the influence-interest matrix. Results from these assessments are provided in Tables 15-17 below.

Table 15: Key stakeholders/ potential partners – Approach overview

Opportunity association	Stakeholder	Stakeholder strategy	How to approach them
	Danish bio-solution providers	Influence: High Interest: High Partner	The Danish bio-solution providers interested in entering the U.S. market need to be identified, closely involved, and engaged in the project, including participation in the webinars and other meetings afterward. We recommend mapping and contacting the Danish bio-solution companies through the Danish industry organizations in the DMFAs network.
	Danish industry organizations working within the field of bio-solutions	Influence: High Interest: High Partner	Key stakeholder group that can help identify, contact, and motivates the Danish bio-solution providers to take an active part in the initiative. They should be involved from the beginning of the project and informed/engaged throughout the process.
	U.S. food industry associations (see table 14)	Influence: High Interest: High Partner	Potentially important stakeholders that can become a partner for DMFA. Has multiple members within the food sector (both producers and clients) and is actively promoting bio-solutions in the U.S. They should be approached early in the process to be informed about the initiative and to discuss potential involvement going forward (they can potentially use their platforms to inform the members about the initiative and the webinars, etc.).

	<p>U.S. agricultural industry associations (see table 14)</p>	<p>Influence: High Interest: Med Partner</p>	<p>Potentially important stakeholders that can become a partner for DMFA. They have multiple members within the agricultural sector (both feed producers and farmers), and they can act as a facilitator to the potential clients within the agricultural sector. Moreover, they can help to gain a better understanding of the market and how to engage the farmers and food processors in the initiative. They should be contacted early in the process and informed about the initiative to discuss potential interests, roles going forward, and how to best approach and involve various agricultural organizations in the initiative.</p>
	<p>U.S. bio-technology industry associations (see table 14)</p>	<p>Influence: High Interest: High Partner</p>	<p>Potentially important stakeholders that can become a partner for DMFA. They have multiple members within the bio-solution sector (both within the feed and food solutions), and they can act as a facilitator to a potential partnership among Danish and U.S. bio-solution providers. They should be contacted early in the process and informed about the initiative to discuss potential interests and roles going forward.</p>

Source: Ramboll

Table 16: Other important stakeholders to involve/engage – Approach overview

Opportunity association	Stakeholder	Stakeholder strategy	How to approach them
	<p>Potential clients within food production (i.e. traditional food production giants and pure plant-based production)</p>	<p>Influence: High Interest: Med Involve/ engage</p>	<p>Should be reached out and informed about the initiative in connection with the webinars and invited for participation.</p>
	<p>Distributors</p>	<p>Influence: High Interest: Med Involve/engage</p>	<p>Should be reached out and informed about the initiative in connection with the webinars and invited for participation.</p>
	<p>Potential agricultural clients (i.e., large meat and dairy processors, large farmers, and feed producers)</p>	<p>Influence: High Interest: Med Involve/engage</p>	<p>Should be reached out and informed about the initiative in connection with webinars and invited for participation. Consider consulting the U.S. agricultural industry associations before contacting the agricultural clients, to make sure that the benefits of bio-solutions are communicated in the right way.</p>
	<p>Large bio-solution providers established in the U.S. (both Danish and US/international with a significant presence in the U.S.)</p>	<p>Influence: High Interest: Med Involve/engage</p>	<p>They can partner with the Danish companies towards political lobby (regulatory condition improvement) or as a potential client (e.g., for smaller companies that want to sell/lease their solution to another player). Thus, DMFA should involve the stakeholders early in the process to inform about the initiative and invite them to the webinars. It could potentially be as speakers to address the bio-solution industry from a U.S. market player perspective.</p>

Source: Ramboll

Table 17: The remaining stakeholders to keep informed – Approach overview

Opportunity association	Stakeholder	Stakeholder strategy	How to approach them
	Agriculture- and bi-science-oriented universities (see table 14)	Influence: Low Interest: High Consult	Possess important subject matter knowledge that can be relevant for the webinars and attract interest. Furthermore, universities work with a wide range of companies and other stakeholders and can help facilitate collaboration. Should be reached out and informed about the initiative in connection with the webinars and invited for participation (and potential as speakers).
	Startup incubators (e.g., KitchenTown and MISTA)	Influence: Low Interest: High Consult	Similar to the universities, the incubators can act as innovation collaborators and guidance for smaller Danish bio-solution providers. Should be reached out and informed about the initiative in connection with the webinars and invited for participation.
	Californian contract manufacturers	Influence: Low Interest: High Consult	Should be reached out and informed about the initiative in connection with the webinars and invited for participation.
	Regulatory supporting organizations (e.g., National Institute of Food and Agriculture, California State Assembly, and Agricultural Research Service)	Influence: Med Interest: Med Consult	Inform about the initiative and invite to the webinars to create a relationship that can be utilized in the project.
	Regulatory agencies (i.e., the FDA and USDA)	Influence: Med Interest: Low Inform	Although the regulatory agencies are without doubt key stakeholders, due to their administrative nature it is considered that they have limited influence to impact the DK/US collaboration, and relatively low interest to do so. Thus, we recommend reaching out to them with information about the initiative to make them aware. Representatives from the agencies can be potentially invited to the webinars as speakers (e.g., to talk about the regulatory conditions).

Source: Ramboll

8. FINAL RECOMMENDATIONS

Based on the assessment throughout this report and interviews with various market players, Ramboll has derived several recommendations for the Danish bio-solution providers on what to be aware of when considering introducing bio-solutions to the U.S. market:

- 1** **Partnerships with local market players are necessary.** Establishing in the U.S. is both difficult and expensive, therefore new entrants should find partners, i.e. either innovation partners, someone that can help with the regulatory process. Furthermore, although in many ways more favorable than in the EU the U.S. regulatory landscape is both complex and expensive to navigate within, especially in sectors regulated by the FDA. Partners can be either local or large companies with well-established operations and networks all over the U.S. However, when selecting partners, it is important to make sure that they have **similar goals and cultures**. Based on interviews with the various market players, there is a clear indication that more partnerships fail due to cultural reasons than due to unsuccessful technology.
- 2** **Be close to the markets where innovation takes place and to the immediate clients.** Hereunder knowledge centers and hubs (e.g. universities and research institutions), but also close to the clients (in case of enzymes B2B companies producing alternative proteins and close to cattle farmers and or feed producers).
- 3** **Political cooperation can enhance the market conditions and help in positioning.** Due to the lack of a clear regulatory framework specific for bio-solution, the regulatory landscape has a clear optimization potential. To ensure that the framework conditions efficiently facilitate the commercialization of new innovations, companies across the sector need to engage in a dialogue at a political level. While individual bio-solutions companies will in most cases not be able to facilitate political discussions themselves, they can engage with various interest organizations, competitors, and or customers that have the needed resources and ability to influence.

With regards to DMFA's further work on enhancing the Danish – U.S. collaboration within the bio-solution sphere, Ramboll suggests following next steps to kick-start the initiative:

Activity	Responsible party
 <p>The Danish Ministry of Foreign Affairs to set ambition level and a plan for a potential collaboration, including the ultimate goal, milestones, timeline and align on what kind of a role they want to take on (e.g. collaboration enabler, provide guidance through the process, funding, etc.).</p>	DMFA
 <p>Define the audience based on this report & input from various stakeholders (political partners, market players, etc.) to compile a list of companies and organizations that can benefit from the collaboration and thus should be involved in various activities (and what kind).</p>	DMFA supported by Ramboll
 <p>Based on the output from the report, identify and approach the key partner stakeholders that should help drive the project.</p>	
 <p>Prepare information and marketing material introducing and promoting the initiative, i.e. describing the purpose, expected benefits, planned activities, etc.</p>	DMFA (potentially guided by Ramboll)

	<p>Kick-off the collaboration; Invite and engage various stakeholders to be part of the initiative. Be aware of the different types of stakeholders and decide on the strategies for how to approach them. Having a good and well-prepared kick-off is important to ensure that the initiative is credible and gets the needed attention and interest.</p>	<p>DMFA supported by Ramboll</p>
	<p>Facilitate collaboration building; Arrange a number of webinars, potentially targeting various topics or stakeholder groups, to encourage collaboration building across the value chain.</p>	<p>DMFA supported by Ramboll</p>
	<p>Establish an information office to be a contact point where the interested companies can receive information, guidance about collaboration options, be introduced to potential partners, etc. The information office can also be used to keep track of the traction for the initiative and to follow up. To serve its purpose, this option needs to be planned from the beginning and communicated properly.</p>	<p>DMFA</p>

9. APPENDIX

1.1 The U.S. companies working within ingredients and alternative proteins

The list below consists of the organizations in the U.S. that are manufacturers of plant-based and fermentation-derived proteins. Note that the list is most probably not exhaustive and is sourced from Good Food Institute.

Source: <https://gfi.org/resource/alternative-protein-company-database/#ingredients-and-equipment>

Company	Brief Description	Technology focus	Operating regions
A&B Ingredients	A&B Ingredients provides the food and beverage marketplace with a wide variety of unique, clean label ingredients. Each of these ingredients fulfills the needs of manufacturers for health, nutrition, food safety and quality.	Ingredient optimization	U.S. and Canada
ADM (Archer Daniels Midland)	Large global ingredients company. Sells various plant proteins.	Ingredient optimization, Crop development	U.S. and Canada
Afineur	Startup using fermentation to improve plant based food, starting with coffee and chocolate. Also developed a cultured plant based protein (part of a larger business)	Host strain development	U.S. and Canada
AG Commodities	Supplies high quality Certified Organic ingredients in bulk	Ingredient optimization	U.S. and Canada
AGT Foods	Global pulsed ingredients distributor	Ingredient optimization	Global,U.S. and Canada
AlgaVia	Produces algae ingredients to optimize nutrition in foods.	Ingredient optimization	U.S. and Canada
Anchor Ingredients	Ingredients distributor		U.S. and Canada
Arzeda	Uses synthetic biology and computational protein design to create designer fermentation strains with applications in agriculture and ingredients (part of a larger business)	Bioprocess design	U.S. and Canada
Atlast Food Co.	mycelium scaffolds for whole-cut plant-based meat	Ingredient optimization	U.S. and Canada
Austrade	Specializes in non-GMO and Organic food and beverage ingredients	Ingredient optimization	U.S. and Canada
Axiom Foods	Hypoallergenic producer of protein concentrates	Ingredient optimization	Global,U.S. and Canada
BI Nutraceuticals	Offers single ingredients and custom ingredient blends	Ingredient optimization	U.S. and Canada
Biorealize	Startup creating custom microorganisms, including those for food and flavor (part of a larger business)	Ingredient optimization	U.S. and Canada

Company	Brief Description	Technology focus	Operating regions
BioTork	Produces non-GMO omega-3 fatty acids from algae culture (part of a larger business)		U.S. and Canada
Brookside Flavors	Specializes in the natural, organic flavors and ingredients	Ingredient optimization	U.S. and Canada
Calysta	Uses bacterial single cell protein to convert methane to protein for fish and livestock feed	Feedstocks	U.S. and Canada
Caremoli USA	Production and distribution of ingredients, mixes, and semi-finished products	Ingredient optimization	Global,U.S. and Canada
Cellana	Develops algae-based bioproducts, using marine microalgae to photosynthetically produce its ReNew™ line of Omega-3 EPA and DHA oils, animal feed, and biofuel feedstocks.	Ingredient optimization,Feedstocks	U.S. and Canada
CHS Inc.	Large agribusiness. Also provides nutrients and crop protection for farmers	Ingredient optimization,Crop development	Global,U.S. and Canada
CK Ingredients	Supplies specialty innovative raw materials	Ingredient optimization	U.S. and Canada
C-Merak	Canadian-based company producing 100% faba protein, starch, flour and fibre ingredients with no additives or chemicals.	Feedstocks,Ingredient optimization,Crop development	U.S. and Canada
Devansoy	Provides natural, non-GMO, and organic soy products	Ingredient optimization	U.S. and Canada
Dezhou Ruikang Food Co.	Highly technological manufacturer and processor of soybeans	Ingredient optimization	Europe,U.S. and Canada,Asia Pacific
Dipasa USA	Researches and develops sesame seed oil production	Ingredient optimization	Global,U.S. and Canada
DKSH	Offers sourcing, marketing, sales, distribution and after-sales-services across the consumer goods, healthcare, and technology industries		Global,U.S. and Canada
DONGYU USI	Sports nutrition, food and beverage, health and beauty, and pet industry ingredient supplier.	Ingredient optimization	Global,U.S. and Canada
Dupont Nutrition & Health	Produces products with enhanced bio protection and improved nutrition.	Ingredient optimization	Global,U.S. and Canada
Eat Well Group	North 58lobaliz based company that is one of the largest processors of plant based ingredients in Canada along with unique Food Technology in the plant based space.	End product formulation and manufacturing,Ingredient optimization	U.S. and Canada
Emerling International Foods	Family-owned trading, processing, and food storage firm.	Ingredient optimization	U.S. and Canada

Company	Brief Description	Technology focus	Operating regions
Euroduna Food Ingredients	Since more than 20 years EURODUNA Food Ingredients GmbH is distributing ingredients to the Food Industry and has become one of the major importer of Soy Proteins in Germany.		U.S. and Canada,Europe,Asia Pacific
Farbest Brands	Focuses on providing clean-label ingredients with a focus on health and nutrition.	Ingredient optimization	U.S. and Canada
Fuji Oil	Major supplier of specialty fats and oil		U.S. and Canada
Garuda International	Specializes in marketing and sales of natural ingredients.	Ingredient optimization,Crop development	U.S. and Canada
Green Source Organics	Manufacturer of natural ingredients with a specialty focused on producing fruit and vegetable concentrates.	Ingredient optimization	Global,U.S. and Canada
H & A Canada	Serves the food, nutrition, and pet food industries with high quality ingredients and on-time delivery	Ingredient optimization	U.S. and Canada
Ingredion	Makes sweetness, starches, nutrition ingredients, and biomaterials that are used in everyday products from foods and beverages to paper and pharmaceuticals.	Ingredient optimization	Global,U.S. and Canada
Kerry	The most innovative portfolio of Taste & Nutrition technologies and Ingredients & Actives for the global food, and beverage industries. Over the past four decades, our focus on changing lifestyles, the 59lobalization of food tastes and ever-evolving consumer needs has brought us to a market leading global position with operations in more than 150 sites across six continents.	End product formulation and manufacturing	U.S. and Canada,Latin America,Europe,Africa/Middle East,Asia Pacific
Manildra Group USA	Supplier of wheat protein isolates, wheat gluten and starch to food manufacturing companies.	Ingredient optimization	Global,U.S. and Canada
MGP	Leading supplier of premium distilled spirits, and specialty wheat proteins and starches to startups and global corps.	Ingredient optimization	Global,U.S. and Canada
Michroma	Fungal biofactories to produce the next generation of ingredients.	Ingredient optimization	U.S. and Canada
Montana Premier Protein	Producer of highly functional organic, non-pea, pulse protein and starch concentrate to support our customers clean label goals.	Ingredient optimization	U.S. and Canada
Mori-Nu	Makes tofu and soy puree	End product formulation and manufacturing	U.S. and Canada
MTC Industries	Researches, develops, processes, distributes and markets of diverse branded and bulk ingredients.	Ingredient optimization	U.S. and Canada
Natural Products	Producer of high quality soybeans.	Ingredient optimization	Global,U.S. and Canada
New Protein International	Building a highly-sustainable soy protein facility, with an exclusive technology that allows us produce clean-label protein, free of hexane.	Ingredient optimization	U.S. and Canada

Company	Brief Description	Technology focus	Operating regions
Nexcel Natural Ingredients	Integrated distribution sight for a variety of Non-GMO and expeller-pressed natural oils.	Ingredient optimization	U.S. and Canada
Noodelist	US-based company that produces plant-based instant noodles that are powered by super plant Moroheiya.	Ingredient optimization	U.S. and Canada
NuCiCer	NuCicer's customized chickpea varieties with high protein content, targeted functional and nutritional properties, and positive environmental traits will directly impact the nutritional, environmental, transportation, and sustainability needs of the future at the required scale.	Crop development	U.S. and Canada
Nutra Food Ingredients	Professional ingredient supplier for the Nutrition, Pharmaceutical and Food & Beverage industries	Ingredient optimization	U.S. and Canada
Nutriati	A US based ingredient technology company that sells chickpea based ingredients such as chickpea protein, texturized protein, and flour as well as aiding in product development with our ingredients.	Ingredient optimization	U.S. and Canada
Parabel	Developed a new way to optimize the nutrition found in water lentils.	Ingredient optimization	U.S. and Canada
Penta Manufacturing Company	Pioneers chemistry-based solutions for applications including flavoring, coloring, and fragrances.		U.S. and Canada
Plantible	cultivation and extraction processes to grow lemna (protein)	Ingredient optimization,Crop development	U.S. and Canada
Prinova	Provides high-quality ingredients, flavors and value-added solutions to the food, beverage and sports nutrition industry	Ingredient optimization	Global,U.S. and Canada
Puris	Plant-based protein ingredients company. Supplies Beyond Meat with pea protein.	Ingredient optimization,Crop development	U.S. and Canada,Asia Pacific
Renergizr Industries Private Limited	India-based company that produces bio-plant and fruit based ingredients for all types of plant based meat and plant based milk products.	Ingredient optimization,Feedst ocks,Target molecule selection	Global,U.S. and Canada,Latin America,Europe,Africa/Middle East,Asia Pacific
TerViva	Manufactures products using pongamia trees.	Ingredient optimization	Global,U.S. and Canada
AAK	With AAKs AkoPlanet™ plant-based oil ingredients, we can help you make tastier, healthier plant-based foods made with love for people, plants, and the planet.	Ingredient optimization	U.S. and Canada,Europe,Latin America,Africa/Middle East,Global,Asia Pacific,Australia

1.2 Californian alternative proteins manufacturers

The list below consists of the organizations in California that are manufacturing plant-based and fermentation-derived proteins. Note that the list is most probably not exhaustive and is sourced from Good Food Institute.

Source: <https://gfi.org/resource/alternative-protein-company-database/#manufacturers-and-brands>

Company	Brief Description	Product Type	Animal-type Analog	Ingredient Type	Year Founded
JUST	Plant-based company with a clean meat arm. Plant-based products include mayos, salad dressings, and a liquid egg scramble.	Eggs,Whole muscle meat	Chicken	Mung Bean	2011
Jewels of the Forest	Produces mushroom-based jerky	Other meat	Beef/veal	Mushrooms	2016
Urban Remedy	Produces clean label nut milks. Also sells meal plans and cleanses.	Milk		Almond,Cashew,Coconut	2012
Plant Power Fast Food	Vegan fast food chain with five locations in California	Ground meat	Beef/veal,Chicken,Fish	Soy,Wheat	2015
El Burrito	Produces a line of soy-based meat products such as soyrizo, ground meat, taco filing, sausage, and pepperoni	Ground meat	Beef/veal,Pork	Soy	1980
NutPods	Produces dairy-free creamers under the brand name Nutpods. Nutpods is now the highest reviewed dairy-free creamer on Amazon.com and was recently named one of the innovative beverages of 2016 by the Specialty Food Association.	Other dairy		Coconut,Almond,Oat	2013
Unisoy	Maker of plant-based jerky	Ground meat	Beef/veal	Soy	2016
Hooray Foods	Produces plant-based bacon	Other meat	Pork	Rice,Tapioca,Coconut	2019
Plant Veda	Produces probiotic beverage and Indian cashew Lassi. Founders have another company, Karma Milk Private Limited, which produces the same products in India.	Other		Cashew,Oat	2019
Harmless Harvest	Maker of dairy free yogurt and milk (and coconut drinks)	Milk,Other dairy		Coconut	2010
Grounded Foods	Maker of plant-based cheese from cauliflower and hemp	Cheese		Cauliflower,Hemp	2019
Miyoko's Creamery	Produces artisanal cultured nut-based cheeses	Cheese,Other dairy		Oat,Cashew	2014

Company	Brief Description	Product Type	Animal-type Analog	Ingredient Type	Year Founded
The Amazing Protein Co	Produces LIKA brand protein and meat alternatives. Used as a plant-based eco-friendly filler in ground beef or as a standalone meat substitute.	Ground meat	Chicken,Beef/veal	Wheat	
Daring Foods	Maker of plant-based chicken	Other meat	Chicken	Soy	2018
Leaf Cuisine	Produces cashew-based cheeses	Cheese		Cashew	2004
Moku Foods	Mushroom and plant-based jerky	Whole muscle meat	Beef/veal	Mushrooms,Coconut	2019
Pop & Bottle	Produces oat and almond milk lattes sweetened by dates	Milk		Oat,Almond	2015
Kite Hill	Produces plant-based cheeses, yogurts, butters and raviolis.	Other dairy,Cheese		Coconut,Almond	2013
Follow Your Heart	Produces plant-based cheeses, dips, spreads, dressings, Vegeta-naise, and the VeganEgg	Cheese,Other dairy		Canola,Soy	1970
Prana Foods	Produces veggie burgers and cookies	Ground meat,Other		Oat	2008
Impossible Foods	Maker of the Impossible Burger and Impossible Pork. Products use fermentation-derived heme	Ground meat	Beef/veal	Soy	2011
Halsa Foods	Produces oat-based yogurts	Other dairy		Oat	2015
Frieda's	Speciality produce company with a line of soy chorizo (Soyrizo)	Ground meat		Soy	1962
Forager Project	Produces cashew milk, cashew yogurt, juices, shakes, smoothies, and snacks	Milk,Other dairy		Cashew,Coconut	2013
Nate's	Produces plant-based meatballs, Indian-inspired entrees, and falafel (all sold frozen). Parent company is based in India.	Ground meat		Soy	
New Barn	Produces organic almond milk, as well as a buttery spread	Milk		Almond	2015
Outstanding Foods	Produces plant-based bacon chips	Other meat	Pork	Pea	2016
Vegetarian Plus	Produces beef, chicken, turkey, ham, fish, shrimp, and other meat alternative products. Produces various Asian-inspired meat-alternative-centric meals, such as vegan citrus spare rib cutlets and vegan ginger chicken. Sold in the frozen section of many natural foods stores.	Ground meat		Soy	1998
PLANETARIANS	Developer of ingredient technology system designed to upcycle by-products and solid food waste into high-protein high fiber ingredients.	Ground meat	Beef/veal,Chicken,Pork	Pea,Soy	2017
The Abbot's Butcher	Plant-based burgers, meat balls, and ground beef	Ground meat	Chicken,Beef/veal,Pork	Pea,Wheat	2018
Jule's Cashew Brie	Produces artisanal cashew cheeses	Cheese		Cashew	2017

Company	Brief Description	Product Type	Animal-type Analog	Ingredient Type	Year Founded
Mr. Dewie's	Produces cashew-based ice cream	Other dairy		Cashew	2011
Hodo Soy Beanery (Hodo, Inc.)	Produces tofu, soy milk, soy-based meat alternatives including Chipotle's Sofritas, ready-to-eat meals, and yuba (thin veil that forms on the surface of heated soymilk)	Ground meat	Chicken,Beef/veal	Soy	2006
Vixen Kitchen	Produces vegan paleo gelato. Cashew-based, sweetened with maple syrup	Other dairy		Cashew	2013
Loca	Produces plant-based cheese dips	Cheese		Potato	2018
Maika Foods	Maker of a plant-based steak and other meats	Whole muscle meat,Ground meat	Beef/veal		2015
Wildwood Harvest Foods (Pulmuone Foods United States, Inc.)	Produces meat alternatives including veggie burgers and meatless crumbles, tofu, vegan mayo, soymilk, and soy creamer. Parent company is Korea-based but there are corporate, sales and food science headquarters in Fullerton, California with manufacturing enterprises in California and New York.	Other dairy		Soy	2001
Kuleana	Startup working on plant-based fish, starting with akami tuna sashimi	Other	Fish	Pea,Algae	2019
Parmela	Produces Cheeses; shredded and slices	Cheese		Cashew,Coconut,Potato	2014
Three Trees	Produces almond, pistachio, and sesame milks and cold brew coffee. Clean label.	Milk		Almond,Other	2012
Perennial / Willow Cup	Producer of direct to consumer plant based milk	Other		Pea,Rice,Soy	2016
Air Protein	Startup focusing on using a closed loop carbon cycle to create a soybean flour that is 80% protein and grown without land. Flour is then used to create plant-based meats.	Ground meat,Other meat	Chicken	Soy	2019
Wild Earth	Koji-based pet food using fermentation platform and cell-based mouse meat for pet food (part of a larger business)	Pet food		Yeast,Chickpea,Oat,Pea	2017
New Culture	Startup using fermentation to produce animal-free casein for cheese and has started with mozzarella	Cheese			2018
The EVERY Company	Produces egg proteins and supplements using fermentation platform.	Eggs,Other		Yeast	2014
Prime Roots	Startup working on meat analogs made from mycoprotein	Other dairy,Whole muscle meat	Pork,Beef/veal,Chicken	Rice,Pea	2017

Company	Brief Description	Product Type	Animal-type Analog	Ingredient Type	Year Founded
Perfect Day	Produces milk proteins using fermentation platform.	Milk		Whey,Ca-sein	2014
Nutiva	Vegan Ghee. Many other products, primarily coconut oil	Other dairy		Coco-nut,Other	1999
SunRhize Foods (KEMA)	Creators of alternative protein foods made of tempeh	Other meat		Soy	2018
Don Lee Farms	Supplier & co-packer of meat and plant proteins with decades of production know-how and culinary expertise	Ground meat	Beef/veal,Chicken		1982
Cena Vegan	Appears to be foodservice focused (food truck). Produces a variety of plant-based meats focused on clean label and family recipes	Whole muscle meat	Beef/veal,Chicken,Pork		2016
Seva Foods	Produces plant-based freeze dried ice cream and coconut jerky	Other dairy,Other meat		Coconut	2017
Starlite Cuisine	Maker of plant-based enchiladas and taquitos from soy and pea protein	Ground meat	Chicken,Pork,Beef/veal	Soy,Mush-rooms,Chick pea,Pea	2000
Spero Foods	Produces seed-based artisanal cheeses and egg scramble/omelet products	Cheese		Sunflower	2018
Sophie's Kitchen	Plant-based seafood	Other meat,Whole muscle meat,Ground meat	Fish,Shellfish	Pea,Po-tato,Rice	2010
Rebbl	Produces plant-based RTD beverages and milks	Milk		Coconut	2012
Reveri	Produces plant-based ice cream	Other dairy		Al-mond,Tapi-oca	2017
Ripple Foods	Produces pea-based milks	Milk,Other dairy		Pea	2014
Sweet Earth Natural Foods	Produces prepared meals/burritos/breakfast sandwiches, some of which are vegan/vegetarian. Benevolent bacon, veggie saUnited Statesge, and seitan also sold separately	Ground meat,Other meat,Eggs	Chicken,Beef/veal,Pork,Tur-key	Wheat,Soy, Buck-wheat,Pea	1978
Something Better Foods	Plant-based meat developed by Chef Chew	Other meat	Beef/veal,Chicken,Fish	Chick-pea,Soy,Ric e	2011
8th Continent	Produces soy milk	Milk		Soy	2001
24 Vegan	Produces vegan fish sauce	Other	Fish	Soy	2016

Company	Brief Description	Product Type	Animal-type Analog	Ingredient Type	Year Founded
Alpha Foods	Plant-based burritos, chicken, and beef	Ground meat	Chicken,Beef/veal	Soy	2015
Califia Farms	Produces almond- and coconut-based milks, iced coffees, creamers and avocado-based butters.	Milk,Other dairy		Almond,Oat,Coconut	2010
Beyond Meat	Plant-based meat company, publicly traded. Produces the Beyond Burger and Beyond Sausage, among other plant-based meat products	Ground meat,Other meat	Beef/veal,Chicken	Pea,Fava bean,Mung Bean	2009
Cacique	Produces soy sausage, as well as a variety of animal-based sausages and cheeses	Ground meat		Soy	1973
Bolthouse Farms	Produces pea-based milks, smoothies, and salad dressings	Other dairy		Pea,Coconut	1915
Amy's Kitchen	Produces vegetarian and vegan frozen entrees, meals and meat alternatives.	Ground meat	Beef/veal		1987
Blue Diamond Almond Breeze	Blue Diamond's brand of almond milks and almond milk blends.	Milk,Other dairy		Almond	1910
Before the Butcher	Plant-based beef, chicken, and pork	Ground meat	Beef/veal,Turkey,Chicken	Soy,Coconut,Canola	2016
Change Foods	Change Foods is creating animal-free dairy foods by leveraging precision fermentation technology, starting with cheese. We harness the power of microbes instead of animals to create foods that are indistinguishable from their animal-based predecessors on taste and texture, while delivering better for you and more sustainable products.	Cheese,Other dairy			2019
Zen Burger	Produces nut-based burgers, balls and tacos. The company produces Gluten-Free, Soy-Free, Nut-plant based and organic burgers and tacos which are healthy alternatives to current fast foods.	Ground meat		Rice,Sunflower	2013
Eclipse Foods	Maker of plant-based ice cream	Other dairy			2019
Pure Farmland	Maker of high-quality, plant-based ground protein products.	Ground meat	Beef/veal	Soy	2011
Future Farm	Future Farm's mission is to change the way the world eats by leading people away from animal-based burgers, filets and nuggets, by making sustainable, healthy and tasty plant-based food accessible to all.	Ground meat	Beef/veal,Chicken,Pork	Soy,Pea,Chickpea,Beetroot	2019
Nobell Foods	US-based company developing plant-based affordable substitutes to animal products.				2016
Sempera Organics, Inc.	Sempera Organics produces mushroom-based ingredients and proprietary blends for use in alternative protein products.	Other		Mushrooms	2020

Company	Brief Description	Product Type	Animal-type Analog	Ingredient Type	Year Founded
Impact Food	We reimagine sustainable food systems through delicious and nutritious plant-based seafood.	Whole muscle meat	Fish,Shellfish		2021
Jinka	We offer a sustainable, plant-based tuna spread for those looking for a healthy and tasty alternative to tuna.	Other meat	Tuna		2016
Sincarne Inc	Fungal protein	Ground meat,Whole muscle meat,Milk,Other meat,Cheese,Other dairy,Pet food,Eggs,Ingredients		Fungi	2021
Trophic	Developing the most abundant, sustainable, and affordable protein source on earth.	Other meat	Pork	Seaweed	2017
Ademi LLC	San Francisco Bay Area (US) -based startup that specialized development and future production of plant-based seafood	Other meat,Whole muscle meat	Shellfish,Fish	Pea,Algae	2021
Sundial Foods, Inc.	California-based company industrializing extrusion-free processing method for plant-based whole cuts of meat and producing chickpea-based chicken wings with skin, meat, and bone	Whole muscle meat,Other meat	Chicken	Chickpea	2019
Nowadays	California-based company that produces plant-based nuggets emphasizing simplicity and nutritional profile	Ground meat,Whole muscle meat	Chicken	Wheat,Pea	2021
Black Sheep Foods	California-based company that produces plant-based mutton emphasizing taste using Branched Chain Fatty Acids	Ground meat	Mutton/lamb	Pea	2019
NFA Foods	California-based company that produces plant-based egg and meat products	Ground meat,Eggs	Shellfish,Pork		2019

1.3 Californian contract manufacturers

The list below consists of the organizations in California that are providing contract manufacturing services. Note that the list is most probably not exhaustive and is sourced from Good Food Institute.

Source: <https://gfi.org/resource/contract-manufacturing-database/>

Opportunity association	Stakeholder	Brief description	Role in relation to bio-solution providers
	Avid Bioservices	A California-based contract manufacturer focusing on biopharma, but also provides a variety of process development activities, including cell line development and optimization, cell culture and feed optimization, analytical methods development, and product characterization	<p>Contract manufacturer</p> <p>Plant-based technology is not the primary focus of their operations. However, they could potentially still offer manufacturing services to bio-solutions.</p>
	Don Lee Farms	A California-based contract manufacturer, supplier & co-packer of meat, and plant proteins with decades of production know-how and culinary expertise	<p>Contract manufacturer; Guidance</p> <p>Plant-based technology is already the focus of their operations. Thus, they have experience within the area and could potentially offer manufacturing services to bio-solutions.</p>
	Initiative Foods	A California-based contract manufacturer that traditionally produces and markets organic and conventional baby food products.	<p>Contract manufacturer</p> <p>Plant-based technology is not the primary focus of their operations. However, they could potentially still offer manufacturing services to bio-solutions.</p>
	Before the butcher, Uncut	A California-based contract manufacturer “making the best Plant-Based products at a price that everyone can afford..”	<p>Contract manufacturer; Guidance</p> <p>Plant-based technology is already the focus of their operations. Thus, they have experience within the area and could potentially offer manufacturing services to bio-solutions.</p>
	Ventura Foods	A California-based contract manufacturer that traditionally produces and markets food products. The Company offers custom and branded dressings, sauces, mayo, oils, shortenings, margarine, bases, and pan coatings	<p>Contract manufacturer</p> <p>Plant-based technology is not the primary focus of their operations. However, they could potentially still offer manufacturing services to bio-solutions.</p>

	<p>ADF Foods, Nate's Meatless</p>	<p>A California-based contract manufacturer that also has a brand of meatless meatballs</p>	<p>Contract manufacturer; Guidance Plant-based technology is already the focus of their operations. Thus, they have experience within the area and could potentially offer manufacturing services to bio-solutions.</p>
	<p>Real Vision Foods</p>	<p>A California-based contract manufacturer that traditionally produces bars (chilled and dry), bites, and butter as well as cookies in both baked and dried form</p>	<p>Contract manufacturer Plant-based technology is not the primary focus of their operations. However, they could potentially still offer manufacturing services to bio-solutions.</p>
	<p>Farm Foods USA Inc.</p>	<p>A California-based contract manufacturer producing private label products in the alternative protein category for some of the world's leading retailers. Develop formulations that can be adjusted to suit customer-specific needs or work directly to develop a unique formulation capturing customers' specific flavor and nutrition profiles.</p>	<p>Contract manufacturer; Guidance Plant-based technology is already the focus of their operations. Thus, they have experience within the area and could potentially offer manufacturing services to bio-solutions.</p>