THE GOOD FOOD INSTITUTE

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Office of Science and Technology Policy
Executive Office of the President
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RE: Docket No. 2019-19470, Request for Information on the Bioeconomy

The Office of Science and Technology Policy (OSTP) defines "bioeconomy" to include products and technology "derived from biologically-related processes and science that drive economic growth, promote health, and increase public benefit." A rapidly expanding part of our nation's bioeconomy is the use of "alternative proteins" to create food from plant proteins, non-animal cell culture, recombinant proteins, and animal cell culture.

Alternative proteins are approaching a technological tipping point and can realistically be expected to serve as the foundation of the U.S. food system in the near future provided adequate research and development is supported and disseminated. In a 2017 report on future products of biotechnology, the National Academies of Sciences, Engineering, and Medicine named alternative proteins as an area with high growth potential.[1] If successfully implemented, a food system based on alternative proteins has the potential to grow the U.S. economy, sustainably feed 9.7 billion people globally by 2050, and address global public health issues such as antibiotic resistance and zoonotic threats.

Governments worldwide are beginning to take notice and invest in research and development of alternative proteins. If we want the United States to become the global leader of the alternative protein sector of the bioeconomy, we must make a concerted effort to fund the science and technology that will enable this new sector to flourish. Key components include intramural research at federal agencies, extramural grant programs explicitly for alternative proteins research, establishment of alternative protein research centers and academic majors at universities, a nationwide network connecting research nodes, and deep collaborative effort with industry.

Therefore, we respectfully recommend that the United States make investments on par with other initiatives such as nanotechnology and renewable energy to lead the world in building a robust bioeconomy. Specifically, we request that OSTP:

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[1] Nat'l Acads. of Scis., Eng'g, & Med., *Preparing for Future Products of Biotechnology*, 52-53 (2017), https://bit.ly/2MG2Jes.

- Work with the Office of Management and Budget to identify new and existing research funds across multiple agencies that could be directed to grow this sector of the bioeconomy (considering, among others, the Departments of Agriculture, Defense, and Energy, as well as the National Science Foundation, the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, the National Institutes of Health, and the National Institute of Standards and Technology);

- Encourage all relevant agencies to support research in alternative proteins;

- Establish an interagency initiative among these agencies, similar to the National Nanotechnology Initiative, to identify and perform the research and development that will remove the technological barriers currently facing the alternative protein sector of the bioeconomy; and

- Ensure interagency coordination in such research efforts to improve efficiency, minimize duplication of effort, and grow workforce talent.

Below, we provide a brief introduction to the technological processes of alternative proteins, with a focus on plant-based and cultivated meat production. We then provide additional details on research and development needs, workforce development, and infrastructure creation (as outlined in the Request for Information) for the alternative protein sector of the bioeconomy.

I. Alternative Proteins Represent a Sector of the Bioeconomy with Strong Growth and Economic Potential.

Nearly every aspect of our economy has the potential to become more sustainable through a multi-sector transition to a more productive and prosperous bioeconomy. A growing body of evidence indicates that this is especially true for agriculture and food.[2] As a part of a robust bioeconomy, alternative proteins offer a sustainable solution to the urgent challenges facing our global food supply while also presenting tremendous economic opportunities.[3] Recent successes of the plant-based Beyond and Impossible burgers in fast food restaurants across the nation show increasing consumer demand for and acceptance of alternative proteins and demonstrate the technological capabilities of food companies to create plant-based meats that appeal to a broad base of consumers across the entire country and all demographics.

Alternative proteins fit into one of four categories from a production and infrastructure perspective: plant proteins, non-animal cell culture, recombinant proteins, and animal cell culture. Figure 1 describes these four categories.

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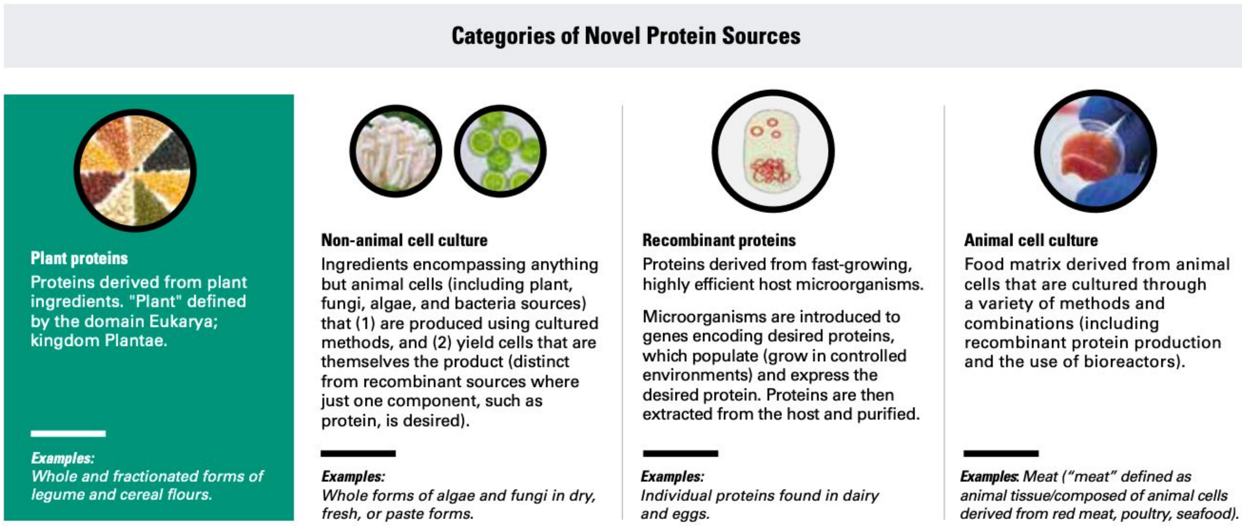
[2] *See* GFI, *Plant-based Meat for a Growing World* (Aug. 2019), https://bit.ly/2mrT5VG; GFI, *Growing Meat Sustainably: the Cultivated Meat Revolution* (Oct. 2019), https://bit.ly/2pBtCKL; GFI, *An Ocean of Opportunity* (Jan. 2019), https://bit.ly/2p0Am4M (this action paper can be made available by request).

[3] *See* GFI, *Plant-based Market Overview*, GFI Blog: Market Research (July 2019), https://bit.ly/2Pu5O2k (click "Market Overview" subheading).

Figure 1: Categories of Novel Protein Sources[4]

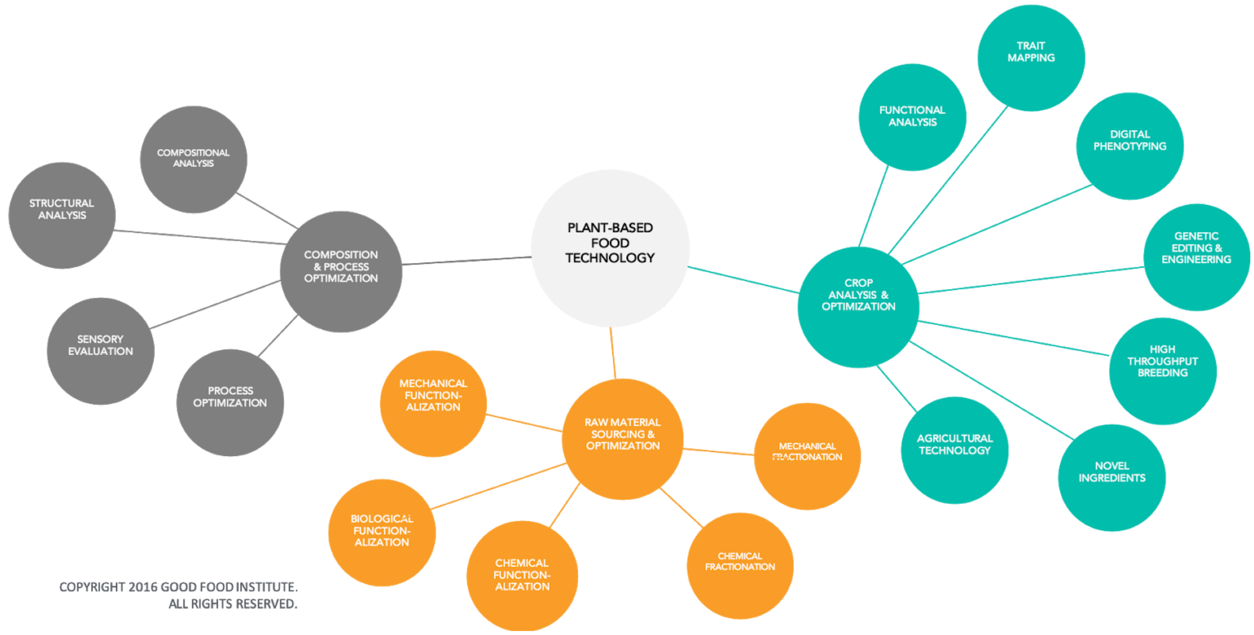


Continued innovation in the alternative protein sector requires a corresponding development of relevant technologies. This will require both basic and applied scientific research in many interrelated areas, each of which presents unique challenges and opportunities for meaningful scientific and technological advancement.

The alternative protein most familiar to Americans is plant-based meat. Though plant-based alternatives to conventional meat have existed for hundreds of years in simple forms such as tofu (soybean) and seitan (wheat gluten), recent advances in science and technology have enabled enterprising companies to biomimic animal meats from component parts of plants with increasing accuracy. This biomimicry typically consists of processing plants with high protein content, such as grains and pulses, into protein isolates and concentrates. Through careful selection of the ingredients and control over the process, foods with the familiar tastes and textures of conventional animal meat can be made. With the development of these technologies has come a new nomenclature: "plant-based meat." Figure 2 depicts a plant-based meat technology mind map to illustrate the numerous areas involved in the production of plant-based meat.

[4] MJ Kinney, *Formulating with Animal Free Ingredients,* Inst. of Food Technologists (June 2019), https://bit.ly/2o6VTsb (containing additional information about these four protein categories).

Figure 2: Plant-based Meat Technology Mind Map



Another alternative protein is cultivated meat, which is sometimes called cell-cultured or cell-based meat. Cultivated meat is produced through a novel application of tissue engineering technology to food. Cultivating meat requires a small sample of animal tissue the size of a sesame seed to grow many pounds of meat in a cultivator, similar to growing a plant from a cutting. Nutrients such as salts, sugars, and fats are added to the cultivator, along with growth factors that nourish the cells and direct their growth and differentiation. In the span of four to eight weeks, depending on the type of meat being produced, animal meat can be grown without the animal. Continuous manufacturing processes could allow for continuous harvesting of meat. This technology was originally pioneered with funding from NASA in 1998 through a small business innovation research (SBIR) grant[5] and more recently entered mainstream awareness when Dr. Mark Post, a tissue engineering professor at Maastricht University, showcased a proof-of-concept cultivated meat burger in 2013.[6] While these products are not yet commercialized, they are on the horizon and constitute only the beginning of what this technology has to offer. Figure 3 illustrates the technology areas involved in the production of cultivated meat.

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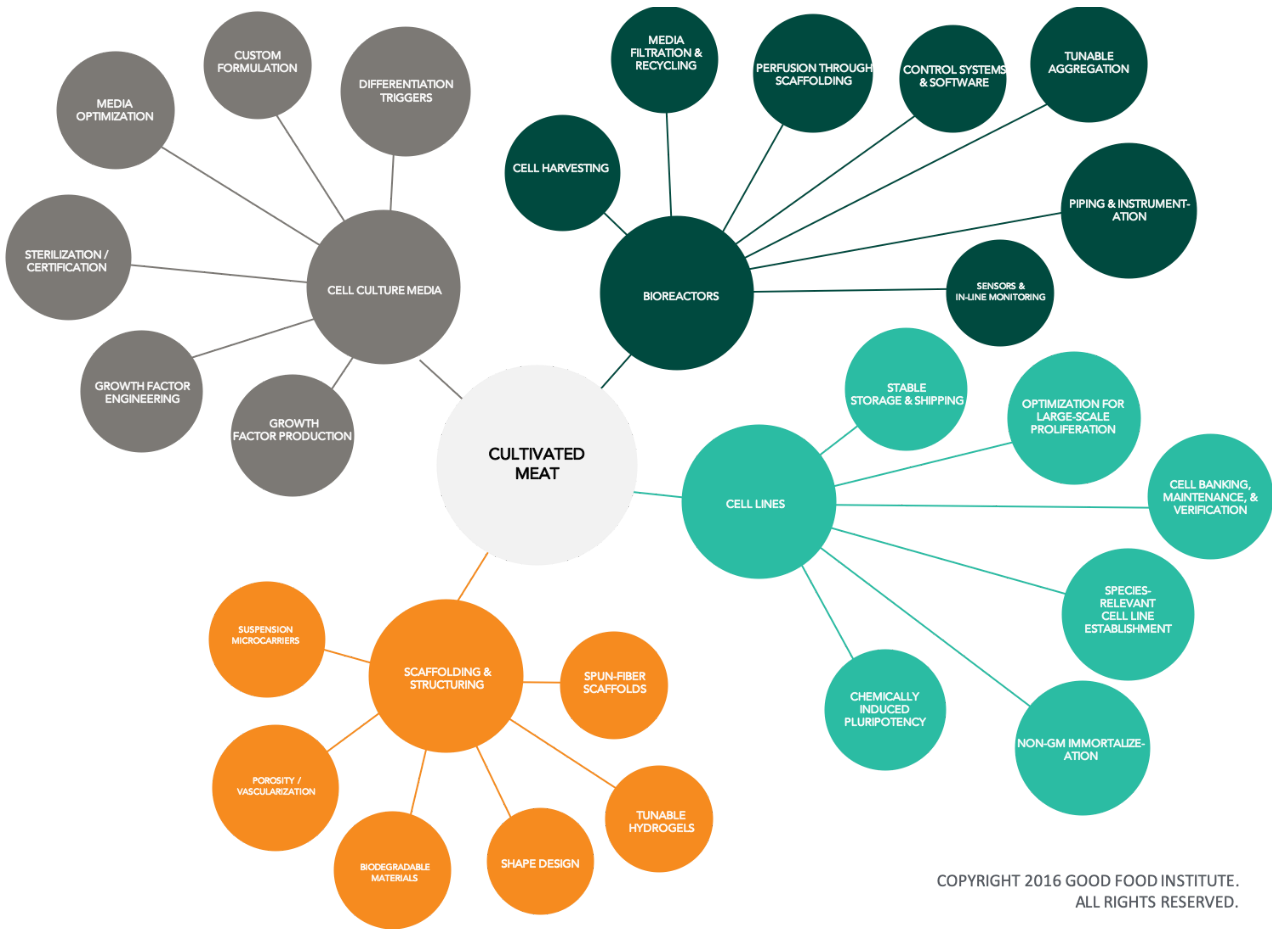
[5] *An In Vitro Edible Muscle Protein Production System*, NASA (1998), https://go.nasa.gov/2oUbhZp.

[6] Hailey Reissman, *Meet the new meat: A TEDx talk to pair with the first lab-grown hamburger*, TED Blog (Aug. 6, 2013), https://bit.ly/2Bvf3en.

Figure 3: Cultivated Meat Technology Mind Map



II. Investing in Alternative Protein Research and Development Would Make the United States a Global Leader in Both Agriculture and the Bioeconomy.

To establish itself as a global leader in the alternative protein sector of the bioeconomy, the United States must invest dedicated funding into plant-based and cultivated meat research and development. U.S. leadership in this sector cannot be taken for granted, as other governments are beginning to recognize alternative proteins' value for both their national security and economy and are already investing in research and development. Israel,[7] The Netherlands,[8] and Japan[9] have each invested in cultivated meat companies in their respective countries. Canada is investing more than US$50 million (Can$75 million) in an effort to secure Canadian leadership in the plant protein sphere (the entire endeavor, funded by a consortium, represents a total investment of US$114 million (Can$150 million)).[10] The European Union has approved a four-year research plan

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[7] *See* Niamh Michail, *Aleph Farms CEO on its 3D cultured beef: 'Unlike other companies, our meat grows together like real meat'*, FoodNavigator (May 2, 2018), https://bit.ly/2DXQkT5.
[8] *See* Elie Dolgin, *Sizzling interest in lab-grown meat belies lack of basic research*, 566 Nature 161-62 (2019), https://go.nature.com/2ShIzii.
[9] *See* Helen Marvell, *Japanese Government Part of $2.7 Million Investment in New Clean Meat Brand*, LiveKindly (June 5, 2018), https://bit.ly/2FJdr2r.
[10] *See Program Guide*, Protein Indus. Canada, 5-6 (Apr. 2019), https://bit.ly/2P92vRL.

investing US$9.1 million (€8.2 million) in an effort to future-proof their food system by developing nutritious plant and microbial protein products.[11] India has given grants to multiple research centers for cultivated meat research totaling about US$640,000.[12] Finally, Singapore — the city-state with a population and GDP less than two percent of that of the United States — is investing US$535 million in research to position its economy at the cusp of the high technology economy, including research on alternative proteins.[13] As a leader in agricultural and scientific innovation, the United States can and must invest in these technologies so as not to be left behind.

The alternative protein sector is expected to develop at a rapid pace over the next decade. We believe that the United States, with its history of scientific leadership and involvement in the formation of cultivated meat as a market sector, is uniquely positioned to lead this charge. In line with the White House's FY2021 research and development budget priorities, the United States should boldly lead the world in accelerating alternative protein research by creating external research programs within relevant agencies, directing the appropriate internal research agencies to carry out specific research programs, connecting researchers from across the nation through a networked infrastructure, and establishing research centers explicitly for the advancement of alternative proteins.[14]

➢ *Commitment to the alternative protein sector will solidify the United States' role as a continued leader in agricultural innovation and will help prepare the United States to remain competitive as the bioeconomy expands.*

Currently, the vast majority of alternative protein research (especially related to plant-based and cultivated meat) occurs in the private sector in the United States. However, total private investments in cultivated meat companies, for example, are still relatively small, amounting to just over $140 million cumulatively as of the date of these comments (and of course not all of this investment was specifically for research and development).[15] To put this amount in perspective: the appropriation for the U.S. Department of Agriculture's Agricultural Research Service (ARS) for fiscal year 2019 alone was $1.3 billion. While private sector research and development is valuable, it does not — and should not — displace public sector funding. Private sector research and development is generally proprietary, meaning that it only benefits the companies investing in it, not the bioeconomy as a whole.

In comparison, publicly funded research can take on longer-term, more basic questions with higher risk but also potentially higher (and broader) value to the economy. Publicly funding work that benefits the entire industry — including entities not yet established — would enable startups

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[11] *See Smart Protein for a Changing World*, CORDIS European Comm'n, Grant Agreement ID 862957 https://bit.ly/342y5Fh (last updated Oct. 14, 2019).
[12] *See* Ramya Ramamurthy, *Indian Government Grants Over $600,000 to Cell-based Meat Research*, GFI (Apr. 26, 2019), https://bit.ly/2Le2Sdv.
[13] Yoolim Lee & Joyce Koh, *Singapore Backs Lab-Grown Meat, Robots in $535 Million Push*, Bloomberg (Mar. 27, 2019), https://bloom.bg/2FI4PKu.
[14] *See* Russel T. Vought & Kelvin K. Droegemeier, Memorandum on Fiscal Year 2021 Administration Research and Development Budget Priorities, Exec. Office of the President (Aug. 30, 2019), https://bit.ly/2zw33br.
[15] *See* Elliot Swartz, *Money Raised*, A Bit of Science, https://bit.ly/31xWG2N (last updated Oct. 2019). This figure was calculated by aggregating the total investments listed in the second graph from the top of the webpage with axes labeled as "Type" and "Money Raised ($MM USD)."

to focus their limited funds and creativity on the commercialization and scale up of new products, creating additional jobs for Americans and bolstering efficiency by ensuring that the same work is not performed repetitively by each company behind closed doors. Much of this publicly funded research could be conducted at universities across the nation. We suggest taking the funding of extramural research one step further by supporting the creation of physical research centers dedicated to alternative protein research.

Longer-term plant-based and cultivated meat projects that fall within the pre-competitive space are also suitable for intramural federal agencies to carry out. Such projects include (but are not limited to) the following types of research:

- Plant breeding, genome sequencing, and mapping of cultivars for plant-based products. These studies are important for identifying desirable traits for selection and use by all segments of the plant-based alternative proteins industry.

- Selection and immortalization of standardized cell-lines for use in cultivated meat. This research would oversee the establishment of an ever-expanding library of cell lines accessible to researchers and industry much in the same way that the NIGMS Human Genetic Cell Repository operates for medical research.[16]

Long-term work such as this fits in well with the goals and expertise of federal agencies and we therefore recommend that OSTP identify and direct relevant federal agencies to include these kinds of projects in their research and development plans.

In *Jump-Starting America*, authors Gruber and Johnson point out that nearly every innovation of the post-WWII era relied on federal government support (peaking at two percent of the GDP) and the partnership between the private sector, universities, and the federal government.[17] Federal research and development funding focused on plant-based and cultivated meat as well as other key segments of the alternative protein sector can help recreate that post-WWII partnership and the economic boom it sparked. Because accelerating the alternative protein sector requires addressing many fundamental scientific hurdles that are relevant for industries outside of that sector, publicly funded alternative protein research would benefit adjacent industries, such as regenerative medicine, in a spillover effect. For example, low-cost growth factors and scaffolding materials for three-dimensional tissue growth identified for the production of cultivated meat are likely to be applicable to biomedical tissue engineering applications as well, potentially driving down the costs of complicated medical procedures.

One challenge to facilitating government-funded alternative protein research that OSTP is particularly well suited to address is the multi-disciplinary nature inherent in this work. Alternative protein research involves expertise in agriculture, food science, tissue engineering, mechanical engineering, and more. Existing research agencies do not typically encompass all of these disciplines. Thus, new research funding programs that cross-cut existing agency boundaries

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[16] NIGMS Human Genetic Cell Repository, Nat'l Inst. of General Med. Scis., https://bit.ly/2BCnrIQ (last updated Sept. 26, 2018).

[17] Johnathan Gruber & Simon Johnson, *Jump-Starting America: How Breakthrough Science Can Revive Economic Growth and the American Dream* (2019).

are needed. For example, basic research into animal protein component identification, induced pluripotent stem cell creation (i.e., reprogrammed cells with the potential to become any cell type), development of cell differentiation techniques, and development of novel food processing techniques could all fit within the purview of an alternative protein basic science program. Applied research into alternative proteins could include research to develop new products, enhance nutritional value, source ingredients, optimize culture medium, design manufacturing facilities, and solve scale-up problems. The broad nature of this work requires the expertise of several federal agencies, including the U.S. Department of Agriculture's Agricultural Research Service (ARS) and National Institute of Food and Agriculture (NIFA), the U.S. Department of Health & Human Services' National Institutes of Health (NIH), and the National Science Foundation (NSF). Thus, we feel strongly that OSTP should build a network analogous to the National Nanotechnology Initiative with similar investments ($29 billion from 2001-2020) to enable collaboration between government, industry, and academia, leading to collaborations that are likely to result in leaps forward for the plant-based and cultivated meat industries.[18]

III. Training a Highly Skilled Workforce Is Required for Successful Realization of an Alternative Protein Bioeconomy Sector.

The alternative protein sector is expected to create a large number of skilled jobs. To begin with, more researchers will be vital to the expansion of the sector. Current researchers involved in alternative proteins come from a broad range of backgrounds, from engineering, biology, and chemistry to food science and nutrition. These pioneers are working at the boundaries of their expertise on multidisciplinary teams. As the industry develops, its workforce will need to become interdisciplinary rather than multidisciplinary — in other words, rather than bringing multiple experts together, individuals will be versed in several fields such that they are competent in all required areas of study. Interdisciplinary researchers will be the direct result of intentionally and explicitly funding research in alternative proteins. The next generation of interdisciplinary researchers will be trained through majors in alternative protein food science and they will develop their skills through dedicated funding of programs and research centers focused on alternative protein research and development.

Product formulation and engineering will likewise require people with a broad range of skills and talents and will therefore draw heavily from the research community. These people will be responsible for applying their scientific backgrounds to formulating new products, developing production techniques, and generally incorporating cutting edge scientific findings into food production. This workforce will require engineers (bioengineers, chemical engineers, mechanical engineers, and tissue engineers), biologists (cell biologists, molecular biologists, and plant biologists), food scientists, nutrition experts, and biochemists (specializing in protein chemistry). Even at this early stage, industry leaders have expressed difficulty finding and hiring talent to fill these roles. Thus, training and recruiting top talent currently represents a significant challenge to the industry as a whole.

Finally, once alternative proteins become established, much of the workforce manufacturing these products on the factory floor will resemble that of other sectors, such as breweries and modern

[18] *Supplement to the President's 2020 Budget*, Nat'l Nanotechnology Initiative, 3 (Aug. 2019), https://bit.ly/2oV3kDh.

food production facilities. Government-run workforce training programs, analogous to the Solar Training program operated by the Department of Energy, can help accelerate the transition to alternative proteins by rapidly expanding the number of American workers prepared for new positions in alternative protein production.[19]

The government must continuously engage with the alternative proteins industry. Involving industry as key stakeholders in government-funded research programs will both advance the needs of the alternative protein sector and shape the skills of their desired workforce. Other mechanisms for collaboration between government and industry include work-study and internship programs, jointly funded innovation competitions, career fairs and discussion panels at research centers, and shared intellectual property schemes. Through the participation of industry, the government can ensure that the future workforce required by the alternative proteins industry is adequately trained to catalyze the commercialization of scientific discovery.

The geographical distribution of the alternative proteins workforce is still unknown and highly susceptible to influencing factors. If left to its own devices, the industry is likely to follow traditional pathways towards consolidation and concentration in major population centers. However, through the proper application of incentives, the alternative protein industry could easily become a vast network of local players similar to the craft beer industry, with economic activities contributing to rural development initiatives. These local suppliers can create niches, supply local demands, and utilize local inputs. Such a dispersed industry and workforce would provide other advantages as well, including reduced shipping costs, increased resilience of the food system, and stronger local economies.

IV. Commitment to an Alternative Protein Bioeconomy Will Also Improve Infrastructure and Supply Chains.

The alternative protein industry offers the possibility to produce only the cuts of meat that consumers want and it can rely on just-in-time inventory models to lower costs and reduce waste throughout its supply chains.[20] Current alternative protein supply chains and infrastructure, however, experience pinch points that prevent them from operating at maximum efficiency. In addition to the talent gap and lack of publicly funded research and development discussed above, challenges include limited crop variety, lack of crop optimization, siloing within academia, inefficient processing capabilities of specialty crops, lack of economically viable growth media, unavailability of standardized cell lines, and obstacles to cost-effective bioreactor scale-up.

Until now, the alternative protein industry has piggybacked on the current food system's infrastructure. For example, alternative protein manufacturers use crops that have been optimized for other uses and buy growth media from life science companies that is meant for pharmaceutical manufacturing. This has allowed a nascent industry to test the waters without needing to build its own infrastructure and the results have been overwhelmingly positive. However, if research and

[19] *Solar Training*, Office of Energy Efficiency & Renewable Energy, https://bit.ly/32ERR9l (last accessed Oct. 22, 2019).
[20] *See* Liz Specht, *Alt-Meat Trounces Animal Meat's Massive Inefficiencies*, WIRED (Aug. 19, 2019), https://bit.ly/2TKfERD.

development is confined to the private sector, alternative proteins will develop slowly and experience more difficulty in establishing a new, more robust infrastructure.

A new alternative protein infrastructure might be directed towards greater geographical dispersion. A distributed, robust infrastructure could be achieved by maintaining a low barrier to entry and a highly competitive marketplace. Researchers at federal agencies are already addressing plant breeding and tissue growth, but not with their sights on producing alternative proteins. Directing federally funded research towards alternative proteins would remove barriers to entering the alternative protein market and result in a more advanced and competitive marketplace, assuming successful translation of basic science to applied research and ultimately commercialization. This competition would create a greater diversity of products and require efficiency from participants, similar to the craft beer market.

A new alternative protein infrastructure would lend itself to smaller, more widely distributed facilities and supply networks. Such a system would safeguard American jobs in both farming and food technology and keep money flowing through local economies. A distributed system would create an overlapping network of food protein production to protect against supply chain issues such as drought or batch loss. By diversifying inputs, the system would become more robust to unpredictable agricultural conditions. All these changes would result in greater food security for Americans as the population expands and environmental conditions continue to change.

V. Conclusion

The alternative protein sector of the bioeconomy is approaching a technological tipping point where it can realistically serve as the foundation of the global food system in the near future. If the United States is to solidify its role as the global leader in alternative proteins, it must make a concerted effort to fund the science and technology that will enable the transition to these new protein sources. OSTP can facilitate a successful alternative protein sector by identifying new and existing research funds across multiple agencies, encouraging agencies to support research in alternative proteins, and establishing an interagency initiative to identify and perform research and development and ensure interagency coordination.

We would welcome the opportunity to work with you to grow this sector of the bioeconomy.

Sincerely,

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