Innovation for Protein Diversification
UN Food Systems Summit Solution Cluster
August 20, 2021

Call to Action

This solution cluster calls on public, private, and civil society stakeholders to create a broad-based coalition to accelerate innovation to diversify and scale protein production and consumption. Diversified protein categories included in this cluster are plant-based and aquatic crop-based proteins, fermentation-derived proteins, cultivated meat,[1] high protein plant varieties, and other future foods.

To reduce the ecological footprint of protein protein, while supporting positive public health outcomes and economic development, we recommend stakeholders prioritise these actions:

Build knowledge and evidence on diversified proteins, holistic science-based targets and pathways.	Invest in collaborative scientific research.
	Conduct social, economic, and behavioral research identifying intervention mechanisms.
	Create evidence-based agile guidance.
	Build country-specific pathways to protein diversification.
Drive innovation to reduce barriers and to scale diversified protein production and consumption.	Develop regional and global innovation ecosystems and platform-to-platform collaboration.
	Design and deploy enabling policy incentives and investments in inclusive and scalable technology solutions and public finance.
	Develop science-driven behavioural consumer-facing approaches regarding education, information provision, and motivation to nudge people towards alternative proteins.

Objective

The objective of this solution cluster is to create a broad-based multi-stakeholder coalition for innovation and action to alleviate the pressure on planetary boundaries and health systems driven by population growth and current and projected protein consumption patterns. There are a number of simultaneous paths needed to do this; this solution cluster is specifically focused on the innovation needed in order to diversify and scale protein production and consumption in critical geographies to reduce the ecological footprint of protein, while supporting positive public health outcomes and economic development.

Diversified protein categories that form the basis of this solutions cluster include:

- Plant-based and aquatic crop-based (e.g. seaweed) meat, eggs, and dairy mimicking the taste and texture of their animal-based analogues. These products are easily integrated into daily life without the need to acquire new skills or change cooking behaviour, as they can readily be used in traditional cuisines.
- Fermentation-derived proteins (including microbial, whole-biomass, and precision fermentation) created via yeast, bacteria and fungi, used as a means to produce different types of proteins from various and diversified substrates such as agricultural side streams, carbon dioxide, or sugar.
- Cultivated meat[1] grown directly from animal cells without the need to raise full animals which enables consumers to continue eating meat but in a way that uses fewer natural resources.

[1] Also known as cell-based, cell-cultured, or clean meat

- High protein plant varieties, such as pulses, nuts, peas, whole grains, and seeds, provide high levels of protein, can be consumed without minimal processing, can have positive environmental benefits (including improving soil health), and are generally fairly accessible to consumers.
- Other 'future foods' may have potential for multiple benefits across human health, environmental sustainability, food system resilience and democratization of the food system.

A wide range of protein sources can have important environmental and health benefits. Initial studies suggest significant potential advantages via savings in land-use, water, and energy use for the above protein sets compared to conventional animal protein sources.[2,3,4] Growing certain high-protein crops such as pulses can also have a positive impact on soil health and climate adaptation due to the nitrogen fixing properties of such crops. Furthermore, diversified proteins can help alleviate key social and health challenges such as animal welfare, antimicrobial resistance, and zoonotic disease. Despite these positive indications, innovation for many categories of diversified proteins is at its nascent stage with untapped potential.[5] Certain conditions must be in place for this potential to be realized. For example, widespread substitution of alternative proteins for conventional proteins must occur to maximize benefits relative to the counterfactual (production of the same amount of protein by conventional means to meet future demand). Because alternative proteins have the potential to disrupt complex food systems if they are produced and consumed at large scales, secondary and tertiary effects (some of which may decrease the magnitude of the social and ecological benefits that alternative protein production) can be generated, and must also be considered when evaluating the potential effects of this solution set. For example, will reduced prices for conventional protein sources resulting from competition result in efforts to increase the intensity of conventional production, in turn resulting in negative environmental impacts?

Given the urgent need to reduce atmospheric greenhouse gas concentrations, any strategy aimed at reducing the ecological footprint of protein provision as demands and needs for protein grow should start with an emphasis on finding ways to promote increased consumption of readily available and healthy proteins that fit this profile, such as beans and pulses.

While dietary transitions can play a critical role in meeting challenges stemming from the climate, environment, and malnutrition crises, the well-being of food producers who currently rely on livestock production for their livelihoods must be taken into consideration. The transition, in other words, must be just. History demonstrates that social and environmental change can have the most regressive impacts on those who are already vulnerable. Incorporating the needs and perspectives of those who earn their livelihoods through livestock into policies and programs meant to diversify protein sources will help ensure the outcomes of these efforts are equitable.

Problem

The provision of universally accessible, affordable, healthy and sustainable protein is critical to human nutritional needs and to meet the Sustainable Development Goals (SDGs) and the Paris Agreements. By 2050, the FAO projects a doubling in the production of meat, driven by population and demand growth. Yet, livestock production currently accounts for 14.5 percent of greenhouse gas emissions, uses nearly 80 percent of global agricultural land, and is a leading cause of tropical forest clearing and biodiversity loss. Wild fishery production has leveled off and therefore intensified management will be necessary to increase yields. It will therefore be impossible to keep within planetary boundaries using today's production systems. Additionally, new paradigms for biosecurity are emergently critical as supply chains dependent on industrial animal production increasingly demonstrate their vulnerability to disease outbreaks, as well as contributions to antibiotic resistance.

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[2] The Good Food Institute. Sustainable Meat Fact-Sheet, 2020. https://www.gfi.org/sustainable-meat-fact-sheet/

[3] CE Delft. LCA of cultivated meat. Future projections for different scenarios. 2021. https://cedelft.eu/publications/rapport-lca-of-cultivated-meat-future-projections-for-different-scenarios/.

[4] Santo, R. et al. Considering Plant-Based Meat Substitutes and Cell-Based Meats: A Public Health and Food Systems Perspective, Front. Sustain. Food Syst., 31 August 2020. https://doi.org/10.3389/fsufs.2020.00134

[5] Note on human vs. animal consumption: Although some forms of alternative proteins may have the potential to improve the environmental footprint of animal feed, this solution cluster is focused on alternative proteins for human consumption only. Please refer to the UNFSS livestock solution for animal feed efficiencies.

In order to counterbalance further pressure driven by the forthcoming demand (e.g., overall population growth - 1.8 billion new middle class consumers in this decade alone), *innovation is critical* for food categories with some of the highest environmental impact, and - when consumed in excess or produced with antibiotics - negative health consequences, to ensure the health of people, the planet and the economy, in a locally relevant way. This solutions cluster will help advance SDGs # 2, 3, 6, 8, 12, 13, 14, and 15; seek to deliver on the Paris Agreement targets and contribute in support of the Convention on Biodiversity, amongst others.

Components of This Solutions Cluster

This solution cluster aims to increase the availability, accessibility, and affordability of diversified proteins while ensuring that they are healthy, relevant to a broad range of distinct food cultures, and contribute to mitigation of and adaptation to climate change and biodiversity loss. We propose three areas of innovation to achieve these goals:

1) Build knowledge and evidence on diversified proteins, holistic science-based targets and pathways.
2) Drive innovation around culture-, socioeconomic-, gender-, and age- sensitive strategies to reduce barriers and to scale diversified protein production and consumption.
3) Mobilize cross-sector alliances to deploy these strategies, at global and regional/local levels.

Component #1: Build knowledge and evidence, holistic science- and evidence-based targets and pathways

Four key elements to deliver a strong knowledge basis for a transition to diversified protein systems have been identified:

1) Sustained investment in collaborative scientific research.
2) Social, economic, and behavioral research identifying intervention mechanisms.
3) Evidence-based agile guidance.
4) Country-specific pathways to protein diversification.

Sustained investment in collaborative scientific research

To increase the impact of diversified protein developments to fight the climate crisis, protect biodiversity and improve public health, public sustained investment in collaborative scientific research is needed. Most current research is privately funded, and while this is necessary to bring products to market, the resulting developed knowledge is proprietary and dispersed. These investments are understandably focused on financial returns rather than societal or climate outcomes. Some high-impact solutions are understudied, and market failures remain unresolved. By making publicly funded research open-access (which makes the knowledge and technologies from research publicly available or non-proprietary), barriers to scientific collaboration will be lowered and the pace of knowledge generation and technology transfer will be rapidly accelerated. Public funding of research can also enhance the democratization of the food system. Given the novelty of some new protein sources, many companies and innovators have similar needs for knowledge development and manufacturing innovation in inputs and ingredient identification, processing technologies, plant genetics, and cell biology, among others. Publicly funded research can address these sector-wide needs and avoid the costly duplication of research. It can also be complementary to privately funded research; public dollars aimed at early-stage, pre-competitive research frees up private dollars for product development and commercialization, and the news of public investment may drive further private investment. A mission-oriented approach to research is focused on solving the most pressing challenges to achieve impact more quickly.

Furthermore, a major barrier to scaling research for new and diversified sources of protein is finding capable research partners. Governments and global research entities can solve such network failures by funding public-private partnerships to scale innovation and create a vibrant knowledge ecosystem. In addition, public mechanisms can be designed to intentionally include communities and institutions that may otherwise be excluded. Public funding can be directed at creating new research programs in rural communities, in minority-serving institutions, and in institutions in low and middle income countries to ensure that public innovation is distributed equitably. Social sciences and humanities research should be funded alongside technical research, and these disciplines need to be in dialogue to ensure social and ethical considerations are embedded from the early stages of technological development. Given the multidisciplinary nature of alternative proteins

research, the public sector also has the capability to organize collaborative research networks bringing together scientists, non-profits, producers, farmers, and industry leaders with a variety of backgrounds.

Social, economic, and behavioral research identifying intervention mechanisms
To reach significant change toward sustainable food systems, it is essential that supply-side technology developments are matched with demand-side consumption shifts. This is particularly true for a broad range of readily available proteins. For example, government policies facilitating consumption shifts (e.g. behavior-based nudges and incentives) can support growth in plant-based foods leading to a corresponding decrease in consumption of animal-sourced foods where appropriate. To do so, technical research must be matched and guided by social, economic, and behavioral research identifying intervention mechanisms that drive change.

In addition, social and economic research on how shifts affect food system workers across the value-chain (farmworkers, meat processing workers, farmers, ranchers) in rural and agricultural communities is needed. This research should inform strategies to create a just transition and should be conducted in collaboration with impacted stakeholders.

The same mechanisms proposed in the previous component could be applied here as well, but with a specific focus on stimulating knowledge development and assessment of interventions in the social, economic, and policy domains. See Table 1 for areas of proposed research.

Table 1: Areas of Proposed Social, Economic, and Behavioral Research

Economic	Lessons from past production and investment tax credits, loan and loan guarantee programs that have spurred renewable energy generation and job growth could be translated to alternative protein production.
	Public procurement sends strong market signals to investors and companies by providing a major market. In the U.S. alone, revising federal food procurement standards to meet the Dietary Guidelines for Americans would directly reduce emissions by 3-5 million tons/year, with significant potential indirect reductions.
	As a step toward achieving price parity, subsidies supporting industrialized animal-sourced food production should be repurposed towards subsidy instruments encouraging a transition towards and ongoing support of diversified and sustainable sources of protein.
Regulatory	Modified nutrition requirements
	A "sustainable protein portfolio standard" could be developed mandating that food producers or institutional purchasers meet thresholds such as a percentage of sales from diversified protein sources. This could also be implemented via an optional private sector-led certification program.
Behavioral	Education (see Innovation section below)
	Motivation: Private sector actors have a deep understanding of how to create products that appeal to consumers and stimulate repeat purchase behavior. There is, unfortunately, a lack of corresponding understanding from the public sector of how to motivate consumers toward both sustainable and healthy choices. In Western countries, self-reported intent (for example, to reduce meat consumption) and measurable behavior differ. Investment in understanding the intent-behavior gap will underpin policy-making for a dietary shift.

	Information: Educated and motivated consumers then need a whole range of solutions to help them make the right choices easily. These solutions include simple visual, interpretive labeling, using symbols on packs or on menus, point of sale materials, etc. combined with pricing, access and appeal.
	Food choice is not made in a vacuum, but highly influenced by the choice environment. The most sustainable and nutritious choice is too often not the easy choice. Access to sustainable nutrition is also connected to geographic and socio-economic factors. Research initiatives can identify policy levers that can influence food choice landscapes and encourage action by private-sector actors.
Social	There is little current research aimed at understanding the social and economic implications of diversified protein growth across both production and consumption contexts. Efforts should be taken to identify inclusive pathways across different geographies and stakeholder groups.
	Research to ensure diversified protein production will promote safe, secure, and dignified environments for workers.

Evidence-based agile guidance

Recent years have seen the publication of a fragmented range of Environmental, Social, and Governance (ESG) analyses. Yet there is no commonly agreed ESG framework for a holistic assessment of impacts covering environmental, societal, health and business issues. For proteins in particular, ESG standardization is complicated by the diversity of technologies and company types in the market. The third component of the knowledge solution is thus evidence-based agile guidance to support decision-making amongst investors, civil society, and companies.

An overview of relevant factors is provided in WBCSD's Protein Impact Measurement Framework. The biggest obstacle for investors to fully integrate ESG factors into their strategies is the lack of consistency and clarity around sustainable data metrics and data. A commonly-agreed, science-, and evidence-based framework, applicable to all types of proteins, would provide guidance to facilitate decision-making in the private and public sectors. An accepted and widely-implemented ESG framework would create financial incentives for better decision-making and risk management practices, thus steering the sector towards a more healthy and sustainable food system without necessitating "harder" policy interventions.

Proposed actions toward a global ESG framework

- Establish an independent, rigorous panel composed of high-level experts coming from a diversity of stakeholder groups, to create a consensus standard.
- Publish and regularly update an open-access meta-database of ESG scorecards and measures to achieve harmonization, standardization, and transparency.
- Implement policy frameworks to improve the disclosure of ESG data. FAIRR's Protein Producer index could serve as a model for assessing alternative protein companies' ESG profiles. Companies developing the new suite of diversified proteins could also participate in the Climate Disclosure Project.
- Fund development of third-party, rigorous, independent life cycle analyses (LCAs) to quantify the sustainability of diversified protein production (including projections for future scaled production). Fund systems analysis and conduct social life cycle analyses to assess social impact and evaluate ripple effects on food systems beyond the direct impacts of production and find ways to reduce trade-offs and adverse impacts.

Country-specific pathways to protein diversification

Projections for protein consumption in 2050 as outlined by the FAO point to a looming crisis, with a linear correlation between GDP and meat consumption increases. In comparison, global dietary recommendations are largely consistent and point to increased proportions of fruits, vegetables, and whole grains. Shifts are needed in each region and country, but the change trajectory varies tremendously per country as can be seen in the benchmark between today's food categories consumption and recommended targets provided in WBCSD's Food & Agriculture Roadmap – Chapter on Healthy and Sustainable Diets. Regions of overconsumption co-exist with regions of scarcity and chronic undernutrition. To address this diversity, country-specific pathways to protein diversification need to be developed. Each pathway must consider food security, nutritional quality, environmental sustainability, resource availability, consumer preference, economic development, regulatory context, and livelihoods. Because the pathways will be context-specific, pursuit across different scales, cultures, geographies, economies, environments, and social structures can best be developed in parallel.

A good starting point for the development of country-level pathways is the FABLE Calculator. The FABLE calculator is a framework for governments, businesses, civil society organizations and the scientific community to achieve country-specific changes and global sustainable land-use and food systems. This Excel modelling tool quantifies regional future food demand and the resulting global food security and environmental impacts (food security, GHG emissions, land-use changes and biodiversity). The strengths of the FABLE model are: (1) capacity to consider the role of trade between several countries; (2) national strategies and long-term pathways to sustainable land-use and food systems designed by individual country teams, illustrating national policy objectives as closely as possible.

Proposed attributes of country-specific national protein strategies

- Set measurable targets for protein production and consumption levels in 2025, 2030, and 2050.
- Specify short-, mid-, and long-term solutions for transition actors including farmers, processors, food manufacturers, and consumers, taking into account available natural resources and economic factors.
- Outline approaches to developing knowledge, stimulating innovation, growing human capital, and implementing a supportive policy framework.
- Reflect a thorough survey of expectations from various stakeholder groups, including policymakers, food and agriculture companies, finance/investors, consumers, and citizens, resulting in an inclusive process and broadly-carried strategy plan.

With buy-in from member states and the private sector, these four elements will collectively build a strong knowledge base to accelerate the global growth of alternative proteins.

Component #2: Drive innovation around culture-, socioeconomic-, gender-, and age- sensitive strategies to reduce barriers and to scale diversified protein production and consumption

For protein diversification, innovation is defined in a broad sense including not only technology but also collaboration, knowledge, processes, policy and business models contributing towards better outcomes for people and the planet. Innovation frames how we collaborate and work with different stakeholders, including the most vulnerable; how businesses and governments operate and with whom they engage; how actors throughout the system are incentivized for change; and how we use existing and new knowledge and technologies - be they scientific, indigenous, behavioral, partnership, or other.

Within the protein diversification space, three components have been identified to accelerate innovation:

1) Develop regional and global innovation ecosystems and platform-to-platform collaboration.
2) Design and deploy enabling policy incentives and investments in inclusive and scalable technology solutions and public finance.
3) Develop science-driven behavioural consumer-facing approaches regarding education, information provision, and motivation to nudge people towards alternative proteins.

1) Develop regional and global innovation ecosystems and platform-to-platform collaboration

The need for radical innovation in food systems was widely surfaced during the UN Food Systems Pre-Summit, and through the consultative and inclusionary process in the lead-up to the event. This recognition came in the form of a new appreciation and understanding that innovation is about more than the need for technology development alone. Rather, to drive scale and impact, innovation ecosystems are necessarily inclusive of technology development but also incorporating knowledge, processes, policy, investment, capacity building, value-chain connectivity, and partnership.

Three components will be instrumental for creating the necessary innovation for large-scale protein diversification:

A. Regional innovation ecosystems
B. Global innovation ecosystems
C. Platform-to-platform collaboration

A. Regional innovation ecosystems

Food systems have a unique set of context-specific needs and food cultures that vary depending on markets and regions, and within and across markets, which need to be accounted for and developed accordingly. To accelerate innovation for the diversification of protein, regional innovation ecosystems, or *hubs*, are needed. These hubs are precompetitive and multi-stakeholder, bringing together a variety of actors (including universities, NGO's, governments, startups, mid or large size companies, financial institutions, and venture capital), to foster public-private partnerships. By bringing together stakeholders across the food ecosystem, hubs are positioned by design to bring critical existing innovations to scale, drive new breakthrough initiatives, and share the learnings and knowledge. Uniquely centering these ecosystems on the needs at the country/regional level context will allow for protein diversification solution development that is not generic in nature but rather that:

- Caters to the starting point of protein production, consumption and infrastructure for that region.
- Builds on the protein consumption trajectory based on projected population growth and socioeconomic shifts.
- Takes into account the unique cultural profiles, and is supportive of country-specific Protein Pathways.

A specific region's innovation hub's pathway may therefore focus on innovations in production capacity for some, innovations to drive change in consumption patterns for others, innovation to drive a series of high leverage investments, to shift the political economy, to reinforce positive feedbacks, etc.

Furthermore, basing innovation at the country/regional level can provide a significant space to leverage the knowledge of indigenous populations. For instance, indigenous breeds of plant-based and aquatic crop-based protein, such as bambara groundnut or duckweed, have been under-leveraged as sources of protein in the broader regional or global marketplace. Mechanisms to protect indigenous knowledge, resources, and contributions to the protein diversification space should also be prioritised.

Examples of such regional innovation ecosystems include EIT Food's Alternative Proteins Focus Area for the European Union, Flanders Food in Belgium, Food Valley in The Netherlands, Food Tech Valley in the United Arab Emirates, and the Regional Innovation Hubs developing work in Africa.

B. Global innovation ecosystems

The vast interconnectedness of food markets around the world means that, while providing for local needs, there remains a corresponding need to ensure for interconnected ecosystem development across regions. Retaining knowledge at a regional level may allow for short-term competitiveness that is eventually undermined by longer-term trade or regulatory barriers that stem from a void of exchange.

Global or multi-lateral innovation ecosystems will be critical to share learnings across regions for further diversification of proteins – from south-south developments, to age-specific learnings across geographies, to thematic areas of exchange stemming from likeness of production capacity, international collaboration will be critical to achieving scale. Furthermore, these global innovation ecosystems can help to align food systems

ecosystems with those of other sectors such as health, environment, or consumer protection and education, providing benefits across both food and the adjacent systems in parallel. Regional innovation ecosystems will send signals to ecosystem actors when a trend is already established and there is a need and a will for wide scaling of production and increasing access to mass consumption.

The India – Netherlands Smart Protein Corridor is one such example of critical global-level innovation ecosystems; the UpLink Platform is another, targeting the creativity and expertise of grassroots innovators around the world, and linking them through to business, government and other leadership.

C. Platform-to-platform collaboration

For frontier innovations like alternative proteins, where co-benefits of solutions could deliver positive outcomes for health, environment and new economic growth, platform-to-platform collaborations could play a critical catalyst role in accelerating exchange of best practices, new knowledge and the translation of emerging knowledge and science into new products and services or to adapt existing products and services.

Platform-to-platform collaboration embraces open innovation principles, whereby organizations, ecosystems and platforms go outside their organizational boundaries and establish new and inclusive relationships in defining challenges and identifying barriers to innovation. On this basis, platforms work collectively in delivering future solutions with an impact mindset. Through this, new collaborations and trust across platforms and networks would be achieved.

Platform-to-platform collaboration should be actively embedded in the culture and operations of food systems platforms. Platform-to-platform collaboration also serves as a precursor to establishing collaborative innovation networks, where various ecosystems could connect and work towards a common goal with shared knowledge, financial resources and building on the success of their diverse networks and ecosystems. It would be ideal for the regional innovation ecosystems to establish platform-to-platform collaborations to maximise impact and respond to the urgency of transforming the food systems. Examples of platform-to-platform collaboration would include World Economic Forum-EIT Food collaboration on Carbon+ Farming Initiative and EIT Food-Good Food Institute collaboration on pooling resources and knowledge in advancing protein diversification research and innovation agenda.

2) Design and deploy enabling policy incentives and investments in inclusive and scalable technology solutions and public finance

The second component of the innovation solution is policy incentives and investments. Complementary policy mechanisms are required to build national and regional sectoral developmental frameworks. These mechanisms should enable sectoral growth based on national-level roadmaps. See Table 2 for specific policy recommendations to advance protein diversification.

Domestic Policy	Investment in research and development and pilot facilities to enable protein diversification technology development and drive down costs. Public funding, tailored to specifically leverage and harness regional cross-jurisdictional funding, will enable knowledge transfer and cross-border collaboration, addressing some of the barriers to scale within domestic markets. Priority research areas are listed here.
	Tax credits, financing, and other fiscal incentives to drive early deployment of diversified proteins.
	Develop sensible regulatory frameworks to bring cultivated meat and other novel foods to market.
	Include diversified proteins in public procurement guidelines.

	Drawing on lessons learnt in the green energy transition, implement policy mechanisms to support a just transition for both farmers and workers involved in the conventional animal protein chains who choose to move towards protein diversification.
	Labeling requirements should be sensible and not pose a barrier to market entry so that diversified proteins can compete with animal-based proteins on a level playing field.
	Promote education related policies to create awareness around healthy diets that are good for the people and for the planet. Higher education initiatives to prepare future workers (including new professional skills aligned with the diversified protein industry) and provide a sense of new career opportunities.
Inter-national Policy	Diversified proteins should be integrated within the newly created Agriculture Innovation Mission for Climate (AIM for Climate).
	The world needs a diplomatic forum to promote diversified protein innovation and policy best practices among countries. A ministerial body could be housed as a working group within Mission Innovation provided that partnership expands its scope beyond energy.
	Set aside funding for diversified proteins in the Green Climate Fund.
	Global database platform collecting and connecting information on consumption patterns, prices, market share of alternatives proteins versus other segments, etc. to inform decision making processes.
	Address trade barriers in diversified proteins, including the absence of harmonised tariff codes pertaining to cellular agriculture products and those derived from fermentation, will enable cross-border trade and the globalisation of diversified protein supply chains.

To complement incentives, policy mechanisms coupled with demand-side interventions enabling a structural shift towards diversified proteins will be necessary to provide appropriate market signals. These can include repurposing existing agricultural levies/subsidies and research funding towards diversified proteins, establishing mechanisms to reflect the true cost of food and the potential negative environmental and human health externalities derived from animal-sourced foods, and allocate part of these funds in diversified proteins.

3) Develop science-driven behavioural consumer-facing approaches regarding education, information provision and motivation to nudge people towards diversified proteins

The consumer component of this solution cluster will consist of consumer research, public education campaigns, behavior change interventions or nudges, and developing policies that support the development and adoption of diversified proteins. The knowledge component will inform the strategies for consumer education campaigns and programs and will take into account cultural and local context specific needs, which in turn will support the development of supportive and acceptable policies.

There is a need for a clear understanding of consumer perceptions of different protein sources. We need to identify which set of diversified proteins are appealing to which different consumer groups, and how to most effectively persuade consumers to buy and consume more diversified proteins, while reducing overconsumption of animal products.

There is a need for clear, concise, and consistent consumer education campaigns to make consumers aware of the environmental and health benefits of diversified proteins. There is currently consumer confusion on these points, exacerbated by mixed messaging from governments, hyperbolic claims, unjustified fear, and targeted misinformation campaigns. Government-backed information campaigns, high-integrity marketing by companies, and efforts by unbiased NGOs and other entities to educate consumers on the benefits of diversified proteins.

Universities should also play a role in building support, through knowledge and evidence provision, for alternative protein. For instance, in Brazil, offering Introduction to Cellular Animal Science as a course for Animal Science and Veterinary Students has generated buy-in and support from the animal science and veterinary community for diversified proteins. Another example is Nanyang Technological University which recently approved a new undergraduate alternative protein course designed to build the industry's talent pipeline. A list of university alternative protein curricula is available here.

Incorporation of diversified proteins into national dietary guidelines and public sector procurement mechanisms, could send positive signals for consumers and business alike. Commitments by companies to carry out thorough, unbiased analyses of benefits and risks associated with their products and abide by regulatory processes will also be important for gaining social license. Likewise, public campaigns demonstrating the positive outcomes of alternative protein consumption for both health and the environment are also needed. There already exist an array of solutions that could be implemented at scale like simple visual, interpretive labelling, using symbols on packs or on menus, point of sale materials, etc., combined with pricing, access and appeal.

Component #3: Mobilize cross-sector alliances to deploy these strategies, at global and regional/local levels
Cross-sector alliances are essential to realize the full scope of opportunities that diversified proteins can offer our food system. This solution clusters calls on the global community to join existing efforts or band together to develop new alliances to deploy the strategies outlined above.

Stakeholders
Achieving a radical transformation of global protein systems requires collaboration between public and private stakeholders; member states, politicians, policymakers, philanthropies, ecosystem platforms, financers, farmers, intermediate processors, food manufacturers, and consumers are all essential actors to the transition. Recent years have seen an increasing level of attention to this domain across all categories of actors, with some specific countries and regions aligning more rapidly than others.

National governments have an essential role. Governments can utilise their extensive resources to bring together a cross section of the supply chain, alongside academia and the research sectors. Political will and leadership is essential to success, as demonstrated in several leading jurisdictions. For example, Singapore and Israel have emerged as two leaders in diversified and alternative protein adoption to promote domestic food security and address the climate crisis.

In smaller jurisdictions, leveraging economies of scale through focusing on a smaller number of national-scale projects may enable broader participation. National research budgets should be utilized to kickstart sectoral growth. Likewise, existing infrastructure and value chains should be leveraged to support scale and delivery of new sources of protein at the local, regional and global level.

Researchers, policymakers, alternative protein producers, and businesses need to work together to identify the best ways to communicate this information, share the information with consumers through educational campaigns, and enact policies to further support diversified protein adoption.

National governments have already drafted national protein plans or overall strategies toward sustainable food systems, including Canada, the Netherlands, China, the United Kingdom, Denmark, Norway, and the United Arab Emirates. Other governments have intentionally stimulated technology developments with alternative proteins as one of a number of topics of interest (e.g., Singapore, Israel). In other countries, strong regional initiatives are driving the transition pathway, such as in France and Belgium. International bodies like FAO are increasingly concerned with global protein systems, as are philanthropic organizations. Cluster organizations and ecosystems are emerging to bring actors together to stimulate the transition. Examples of these include The Good Food Institute, New Harvest, ProVeg, Food Valley, The Sustainable Food Initiative, and Food Shot Global. Venture capital is flowing into the diversified proteins space, and public and private financing organizations like Rabobank and the Asian Development Bank are working to develop their own protein-focused strategies to contribute. The private sector is highly dynamic, with innovations emerging from both start-ups and established

multinationals. In several regions, private sector coalitions have emerged, such as the European Alliance for Plant-Based Foods or the Alliance for Meat, Poultry and Seafood Innovation in the United States. Innovative farmer cooperatives, including some supposed "vested interests" are pivoting to diversified sources (e.g. Scandinavian dairy cooperatives or Dutch grower cooperatives). Intermediate processors are working to expand their portfolio of proteins, while struggling to meet capacity demands and cope with sunk-cost investments in traditional sources. Last but not least, plant-based foods manufacturers are eagerly innovating to establish themselves as trusted brands in a rapidly-growing category.

All of this activity indicates growing interest in the field. Given the rapid pace of change, and the growing momentum in this sector, a collaborative framework for change has the potential to deliver a major global impact in the coming years.

Funding

Public, private, and philanthropic funding will be necessary to equitably accelerate the growth of alternative proteins in order to combat the climate crisis, create new economic opportunities, and improve human health. Across history and industries, we know that public-private collaboration is effective and impactful. Government funding and support can effectively accelerate developments in the private sector, which can bring important benefits to the broader society. We can learn from other sectors - especially those that share similarities with diversified proteins, such as the renewable energy industry - that have successfully grown and evolved more rapidly thanks to incentivizing policies and government funding. To date, approximately $112 million has been awarded to alternative protein research and development, which is just 0.004 percent of the $2.6 trillion invested in renewable energy over the past decade.

Funding mechanisms should include:

- Public funding for basic scientific research with mechanisms that encourage global collaboration.
- Public-private funding mechanisms to stimulate pre-competitive investment in sector-wide challenges.
- Mission-directed funding mechanisms for applied research to stimulate private sector collaboration with academics translating high-risk breakthrough technologies to practice.
- Directed mechanisms for funding activities for an innovation-conducive environment, including programs that develop skilled human capital.

Contributions to Goals of All Action Tracks

Action Track #1: Ensure access to safe and nutritious food for all

Diversified proteins offer short- and long-term solutions to eliminate hunger. Increased production and consumption of foods that we already know how to produce and that can deliver protein and micronutrients produced with lower ecological footprints relative to meat (e.g., seaweed, whole grains, beans) offer a way to meet near term demand. Plant-based meat, precision fermentation and cultivated meat production have potential to produce foods that can be significant parts of the solution over the medium to long term. While industrial animal agriculture has made tremendous strides in efficiency on a per-unit basis, producing protein from plants and seaweeds is inherently more resource efficient while providing the vast majority of necessary macro-nutrient requirements for human health. Significant regions of land currently used to grow feed for industrial animal agriculture can instead be used for the production of human food, which could increase available food calories to reduce hunger. The ocean also has vast potential for increased production of protein and micronutrients with low ecological footprint.

Action Track #2: Shift to sustainable consumption patterns

Diversifying agriculture to incorporate diversified protein production is a key strategy to combat climate change and shift to more sustainable consumption patterns. Livestock is responsible for 14.5 percent of global greenhouse gas emissions. The diversification of protein production and resulting shift in consumption can achieve transformative results in planetary and human health, including conserving land for habitat, preserving biodiversity and mitigating climate change.

Action Track #3: Boost nature-positive production

Diversified protein production preserves both water and land. For example, studies show that plant-based meat could reduce over 90 percent of eutrophying pollution, a leading threat to global water quality, compared to conventional animal production. In addition, increasing seaweed production and using it directly as food, as a food additive, or refining it into protein and micronutrients has the potential to regenerate damaged ecosystems and enhance biodiversity

Diversified proteins can generate a greater amount of the protein macronutrient on a significantly smaller land footprint than conventional animal-based production. The land spared can reduce deforestation while providing additional land for regenerative agriculture and ranching practices, natural climate solutions, production of renewable energy, and protection for biodiversity. Policies should be implemented to ensure that these land-use protections are prioritised.

Action Track #4: Advance equitable livelihoods
The growth of diversified proteins can enhance sustainability and resilience in both rural and urban areas throughout the world. For instance, in the ASEAN region, farmers are starting to supplement their incomes by growing mung-bean as an input for plant-based protein products. Growing a greater variety of crops can also help protect these farmers and others against market disruptions. Beyond farmers, a large number of skilled jobs including engineers, biologists, food scientists, nutritionists, and biochemists will be created as the global diversified protein industry grows, and new manufacturing plants will be required for the production of the necessary tools and equipment involved. For example, the International Labor Organization estimates that a transition to a net-zero carbon economy would create 22.5 million jobs in Latin America and the Caribbean in agriculture and plant-based food production, renewable electricity, forestry, construction, and manufacturing.

Investing in diversified protein research and development will also create more adaptable and resilient supply chains. By lending itself to smaller, more widely distributed facilities and supply networks, alternative protein production would create an overlapping network of food protein production to protect against supply chain issues, such as pandemics or drought. This resilient infrastructure will support both economic development and human well-being during times of crisis. For example, existing supply chains were largely incapable of adapting rapidly to rapid changes in demand resulting from Covid-19 pandemic restrictions. A more diversified supply chain that includes alternative protein manufacturing facilities may be able to change product forms and distribution channels to adapt to such changes.

Action Track #5: Build resilience to vulnerabilities, shocks and stress
Accelerating the global growth of diversified proteins can help reduce the risk of future pandemics and the rise of antibiotic-resistant superbugs. Animal agriculture, including aquaculture, uses antibiotics to prevent disease that spreads quickly and easily in confined spaces. These industries consume nearly three-quarters of all antibiotics sold globally. Diversified proteins can be grown and produced without the need for antibiotics, therefore when produced in lieu of conventional animal products, they can help reduce agriculture's contributions to the growing threat of antibiotic-resistant bacteria. Increasing demand for animal protein is a primary risk factor for zoonotic disease emergence. In contrast, diversified proteins can eliminate risk of zoonotic disease spread. As noted above, alternative protein production also provides supply chain adaptability and resilience during times of crisis, like the Covid-19 pandemic.

Women's Empowerment, Gender Equity, and Youth Engagement
Diversified proteins have the opportunity to contribute to a more inclusive and sustainable world. An essential part of this mission is women's empowerment, gender equity and youth engagement. Unfortunately, women continue to be underrepresented in leadership positions in the food sector and the diversified proteins sector is not immune to these challenges. Yet critically, the diversified proteins industry is taking proactive steps to achieve gender equity and women's empowerment. These actions towards women's empowerment are paying dividends with an increasing number of diversified protein start-ups and organizations being founded or led by women, particularly in the Asia Pacific. Over the coming years, the solutions described by this cluster provide opportunities to enhance women's empowerment via a just, gender-sensitive transition. This promise of greater gender equality is supported by an expert analysis of potential impacts of food systems innovations published in

The Lancet Planetary Health, which found that cellular agriculture could have a moderate-strong positive impact on gender equality.

In addition, for undernourished subpopulations, particularly children and women who are pregnant or lactating, diversified proteins could offer a solution to improve their nutritional status via high-quality protein. For example, precision fermentation of proteins is a promising strategy to provide "high-quality, affordable protein sources in low and middle-income countries." As the demand for animal-based proteins grows in the coming decades, cultured milk and egg proteins can also play "an important role in the future of food and supporting global nutrition by enabling access to affordable, nutritious, and high-quality protein for vulnerable populations."

As a nascent industry, many of the barriers which withhold leadership positions from youth, such as not having the necessary years of direct industry experience, apply to a lesser degree for diversified proteins. As such, many diversified protein organizations are led by youth. In Australia, the alternative proteins think tank Food Frontier and non-profit Cellular Agriculture Australia are both led by youth. At least seven Alt Protein Project student groups have been launched at universities. Further, many programs exist which aim to create opportunities for youth in diversified proteins. These include Cellular Agriculture Australia's 'Pathways into Cell Ag' program, Nanyang Technological University's upcoming undergraduate course.

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