CLIMATE ADVISERS

Decoupling Methane Emissions from Meat with Alternative Proteins

RECOMMENDATIONS FOR METHANE PLEDGE PARTICIPANTS

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Executive Summary

Mitigating methane emissions is essential to keeping warming to safe levels. A highly potent greenhouse gas, methane is second only to carbon dioxide in fueling climate change.[1] The amount of methane in the atmosphere has more than doubled since pre-industrial times, largely due to increased use of fossil fuels and growth in the food and agriculture sector – especially in animal protein production.[2] If emissions continue to grow at current rates or even remain stable, it will be impossible to keep global warming at internationally agreed levels of no more than 1.5 degrees Celsius.[3] Fortunately, methane is also relatively short-lived, lasting in the atmosphere for only about a decade.[4] This means that the beneficial effects of reducing methane emissions materialize much faster than with carbon, which lingers in the atmosphere far longer. Tackling methane emissions now could help avoid dangerous climate feedback loops, like those associated with methane pulses from melting permafrost.[5] In fact, if sufficiently ambitious, near-term methane emission reductions could prevent as much as half a degree Celsius in warming by the end of the century.[6] That is why 150 countries have now signed on to the Methane Pledge, an initiative that aims to keep the goal of limiting warming to no more than 1.5 degrees Celsius within reach by reducing global methane emissions by 30% percent by 2030.

Over 90 percent of anthropogenic methane emissions come from just three sources: agriculture, fossil fuels, and waste, in that order.[7] Because the food and agriculture sector straddles the categories of agriculture and waste, food and agriculture are together responsible for the majority of anthropogenic methane emissions, dwarfing those produced by the other main source of methane, fossil fuels.[8] Yet despite their global importance, methane emissions from food and agriculture have received relatively little attention, either in climate change public policy circles generally or from Methane Pledge participant countries in particular. This may be because the solutions are far more complex than in the energy sector. Even so, given the food and agriculture sector's enormous contribution to human-caused methane emissions, the climate community must rise to the challenge posed by rising methane emissions from food and agriculture if we are to avoid unacceptable risks of catastrophic global warming. Methane Pledge participants should lead the way.

To reduce emissions in this sector, Methane Pledge participants should prioritize enteric fermentation, a natural process that occurs as ruminant animals such as cows and sheep digest food. Emitted mostly through burps from livestock, enteric fermentation is the single largest source of methane from food systems by far, and emissions from this source are on track to increase roughly 50% by 2050 as the growing global population and middle class increase demand for animal protein.[9] If this trend continues, it will be impossible to achieve internationally agreed climate goals.[10]

Strategies to reduce direct emissions from ruminant animal production, for instance by manipulating animals' diets and providing them better healthcare, have an important role to

play in mitigation. That is why Climate Advisers and others have called for significant investment in and deployment of these strategies.[11] However, because demand for ruminant meat is expected to grow so much over the coming decades, strategies of this sort can only reduce end-of-century warming from food by around 20 percent.[12] That is why, again and again, researchers who have studied the issue closely have concluded that a suite of interventions including but not limited to these sorts of strategies will be necessary to keep food system emissions in line with climate goals.[13] The single most powerful strategy to drive emissions down further is innovation in alternative proteins, products that aim to provide consumers the sensory experience and nutrition of animal meat using plants, fermentation, or cellular agriculture instead of live animals. Right now, most such products are not competitive on cost and taste with conventional animal meat. However, should this change as a result of significant investment by governments and the private sector in innovation, consumers could add alternative proteins to their diets at much higher rates. Together with interventions that reduce direct emissions from ruminants, alternative proteins could become a key to reducing global emissions from food agriculture at the scale and speed needed to stabilize the Earth's climate in line with global climate.[14]

To help countries advance this key mitigation strategy, the brief offers three strategies and eight specific recommendations both for domestic policy measures and international collaboration to advance alternative protein innovation.

First, countries should **invest in innovation**. In particular, they should:

- Drive domestic growth of the alternative protein industry through targeted policy measures, such as loan guarantees, funding for demonstration projects, and workforce development.

- Join other Methane Pledge countries in a non-binding commitment to increase global public funding for alternative protein innovation to $10.1 billion per year ($4.4 billion for R&D and $5.7 billion for commercialization).[15]

- Create a global network of research centers to advance alternative protein innovation pre-competitively.

Second, countries should work to **mainstream alternative proteins within international climate change processes**. For instance, they could:

- Commit to embedding alternative proteins in national climate change implementation plans (NDCs, or Nationally Determined Contributions), including in food innovation and agriculture-related climate adaptation and mitigation strategies.

- Endorse a non-binding, quantitative, time-bound global goal for reducing enteric methane emissions globally.

Finally, Methane Pledge countries should **engage in international cooperation** to advance alternative proteins. Specifically, they should:

- Create a diplomatic forum for intergovernmental dialogue on advancing alternative proteins.
- Develop bilateral and plurilateral programs on alternative proteins via diplomatic or foreign assistance channels.
- Sign on to and commit to meeting priority international actions developed collaboratively by country signatories to the Agriculture Breakthrough and informed by the Breakthrough Agenda Report 2022.

I. Introduction

Mitigating methane emissions is essential to keeping warming to safe levels. A highly potent greenhouse gas, second only to carbon dioxide in fueling climate change.[16] The amount of methane in the atmosphere has more than doubled since pre-industrial times, largely due to increased use of fossil fuels but also, in large part, from growth in the food and agriculture sector, where the moist conditions that allow methane-producing microorganisms called archaea to proliferate abound.[17] If emissions continue to grow at current rates or even remain stable, it will be practically impossible to keep global warming at internationally agreed levels (no more than 1.5 degrees Celsius).[18] Fortunately, methane is also relatively short-lived, lasting only about a decade in the atmosphere once emitted.[19] This means that the beneficial effects of reducing methane emissions materialize much faster than with carbon dioxide, which lasts far longer. Consequently, tackling methane emissions now could help avoid dangerous climate feedback loops, like those associated with methane pulses from melting permafrost.[20] In fact, if sufficiently ambitious, near-term methane emissions mitigation efforts could prevent as much as half a degree Celsius of warming by the end of the century.[21] That is why 150 countries have now signed on to the Methane Pledge, an initiative to keep the goal of limiting warming to 1.5 degrees Celsius within reach by reducing global methane emissions 30 percent by 2030.

Over 90% of anthropogenic methane emissions come from just three sources: agriculture, fossil fuels, and waste, in that order.[22] Because the food and agriculture sector straddles the categories of agriculture and waste, food and agriculture are together responsible for the majority of anthropogenic methane emissions, dwarfing those produced by the other main source of methane, fossil fuels.[23] Yet despite their global importance, methane emissions from food and agriculture have received relatively little attention, both in climate change public policy circles in general and from Methane Pledge participant countries in particular. This is likely due, at least in part, to how much more complicated the sector is compared to the other main source of methane emissions, fossil fuels. There, both the problem and the solutions are straightforward: the problem is that the extraction, processing, and combustion of fossil fuels produces methane, and the solutions are to transition to renewables and electrify end uses such as vehicles and HVAC units. In food and agriculture, by contrast, the solutions are myriad, and many of them only tackle a small fraction of the sector's emissions. Even so, given the sector's enormous contribution to anthropogenic emissions, the climate community must rise to the challenge posed by methane emissions from food and agriculture to avoid unacceptable risks of catastrophic global warming, and Methane Pledge participants should lead the way.

The aim of this brief is to provide guidance for policymakers and advocates in Methane Pledge participant countries wishing to mitigate methane emissions from food and agriculture. The brief argues that production-side interventions to reduce the methane intensity of livestock production will not be enough on their own to align methane emissions from food systems with Paris goals. In addition, it argues that innovation in alternative proteins—products that aim to provide consumers the sensory experience and nutrition of animal meat using plants, fermentation, or cellular agriculture—is a key strategy for filling this gap. To help countries advance this key mitigation strategy, the brief offers three strategies and eight specific recommendations both for domestic policy measures and international collaboration to advance alternative protein innovation.

What are alternative proteins? There are two primary types of alternative proteins: plant-based and cultivated. Just as the goal with renewable energy and electric vehicles is to make them interchangeable with conventional energy and combustion-powered vehicles, so too are plant-based and cultivated meat focused on winning in the marketplace by producing products that taste the same or better to consumers and that cost the same or less, thus requiring no intentional behavior change.

- Plant-based meat and seafood are made from plants but reproduce the taste and texture of animal-based products. The products are focused on fully satisfying meat-eaters. Because their production is so much more efficient than conventionally produced meat, as they scale, they should be able to compete on price.
- Cultivated meat and seafood are real animal products cultivated directly from animal cells. The resulting meat is identical to conventional meat, and, as with plant-based meat, scaling up should allow prices to come down such that it will compete in the marketplace with conventional meat.
- To date, no plant-based or cultivated meat product both tastes the same or better to consumers of meat and costs the same or less. Yet the pace of innovation on alternative proteins has been impressive, with cost and taste improving rapidly.
- Just like electric cars and renewable energy, alternative proteins are speeding down the cost curve and should prove highly attractive to general consumers as soon as they meet price and taste metrics.

II. Why Reducing Enteric Methane Emissions is So Important

Accounting for 45 percent of methane from food systems, enteric fermentation—a natural process that occurs as ruminant animals such as cows and sheep digest food—is by far the largest source of methane from food and agriculture.[24] What's more, emissions from this source are on track to increase roughly 50 percent by 2050 as the growing and increasingly well-off global population eats more and more ruminant meat.

This trend is incompatible with internationally agreed climate goals. A recent analysis finds that unless current dietary patterns and agricultural production practices change, global food consumption alone could increase global temperatures by as much as 1.1 degrees C above present-day levels.[25] Strikingly, the analysis also found that just three high-methane food groups—meat, rice, and dairy—account for more than three quarters of future warming from food. Around half of these projected food-related temperature increases are due to consumption of ruminant meat and dairy alone (see Figure 1 below).[26] Because we have already seen about a degree of warming since pre-industrial times, this means that we cannot hope to limit warming to 1.5 or even 2 degrees C without reducing methane emissions from food systems. Since enteric methane accounts for the plurality of food system methane, it will be practically impossible to meet climate goals without significantly reducing methane from ruminants.[27]

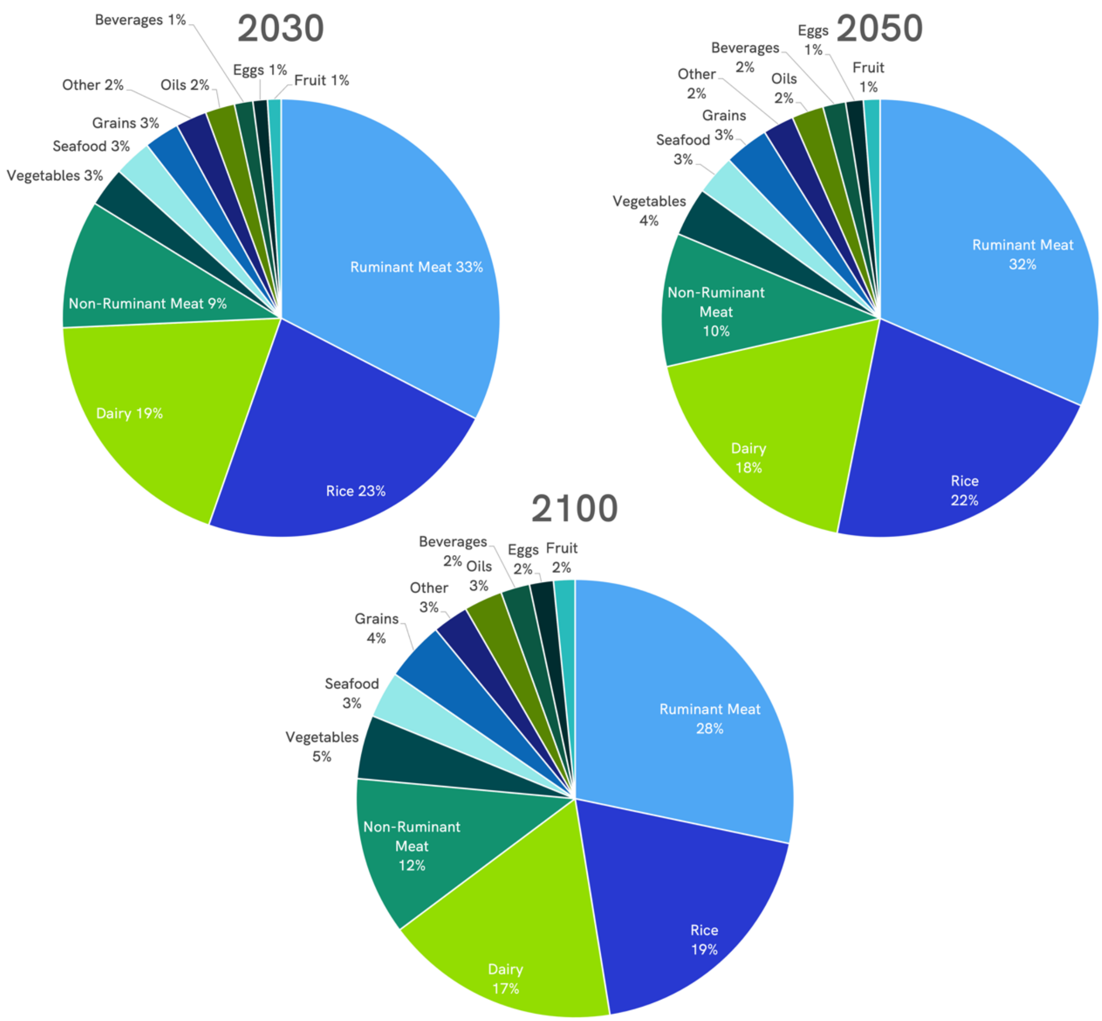

Figure 1. Relative contribution of food groups to future warming from food in 2030, 2050, and 2100. Source: Ivanovich, et al., "Future Warming from Global Food Consumption."

III. Alternative Protein Innovation: a Key Strategy for Reducing Enteric Methane

What should Methane Pledge countries do to reduce enteric methane emissions?

There is a real role here for interventions that reduce the methane intensity of ruminant meat and milk, such as feed additives, vaccines, grazing management, selective breeding, better animal healthcare, and changes in animals' diets. This is why Climate Advisers and others have called for major international investments in efforts to increase uptake of relevant productivity-enhancing practices and improve key technologies.[28] However, research shows that, because of the projected increase in demand for ruminant meat over the coming decades, these interventions will not reduce enteric methane emissions enough to bring food system methane emissions in line with climate goals. For instance, one recent analysis found that interventions that aim to improve production of the most methane-intensive foods can only decrease expected warming by about 0.2 degrees C, leaving as much as 0.9 degrees C of additional warming from food consumption unaddressed.[29] See Figure 2 below.

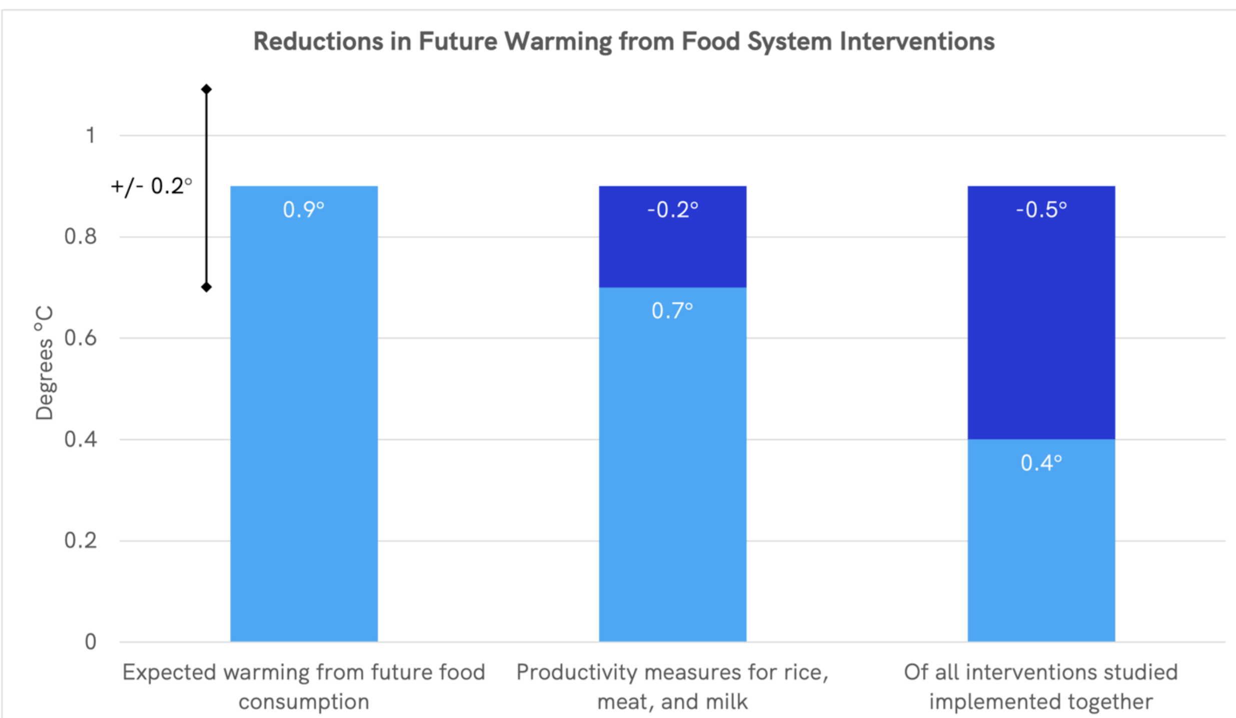

Figure 2. Note that productivity measures can only reduce future warming from food consumption by 0.2 degrees Celsius. Source: Ivanovich, et al., "Future Warming from Global Food Consumption."

Similarly, another set of researchers found that, even in the highly unlikely event that we see 100% adoption of the two most effective production-side interventions to reduce livestock methane, projected increases in milk and meat demand would entirely offset the resulting methane reductions by 2050, pushing emissions too high to limit warming to 1.5 degrees C.[30] See Figure 3 and box below. In short, the research is clear that, if we are to limit warming to safe levels, we cannot just focus on measures that reduce the methane intensity of livestock production.

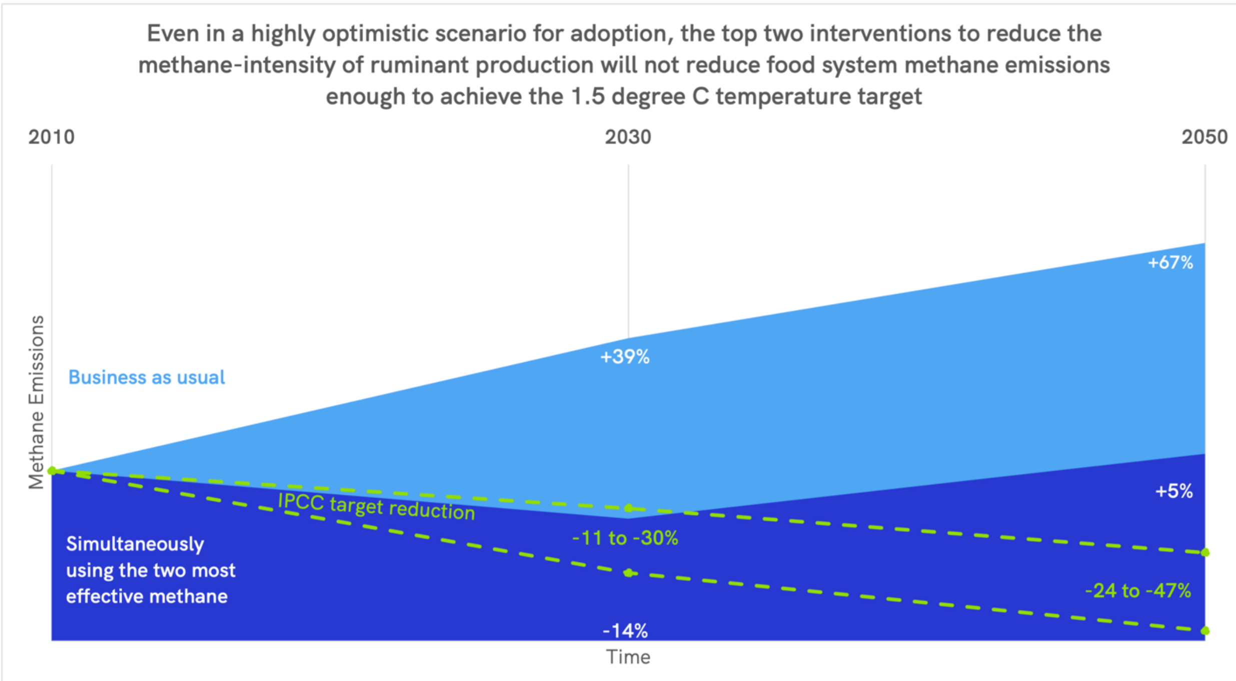

Figure 3. Results of an analysis by Arndt, et al. of the mitigation that could be achieved through 100% adoption of the two most effective strategies for mitigating direct emissions of methane from ruminants, namely increasing feeding levels and using methane inhibitors. Adapted from Aronson, "Full adoption of existing mitigation strategies can help meet livestock methane reduction targets by 2030."

The Importance of Adoption Rates for Livestock Interventions

To study the technical mitigation potential of the two most effective strategies for reducing the methane intensity of ruminant meat production (increasing feeding level and using methane inhibitors), Arndt et al. modeled the effects of 100% adoption of these two strategies (see Figure 3). Further social scientific research is needed to understand what adoption rates are most likely; however, there is reason to believe that 100% adoption is unlikely, at least in the near term, since various practical obstacles stand in the way. For instance, farmers and ranchers currently lack financial incentives to use methane inhibitors. Consequently, the real, practical mitigation potential of these two strategies is likely lower and the need for further strategies to lower emissions from livestock significantly greater than Figure 3 suggests. (For further details regarding practical difficulties surrounding deployment of these and other similar enteric methane mitigation interventions, see McBee,"Reducing Methane Emissions from Food and Agriculture," pp. 5-8.)

These considerations have led many to conclude that, hard as it might be to do, we have no other option than to try to persuade people to eat differently. But there is another option. Instead of trying to drastically change consumers' behavior, we can simply provide them with alternatives to ruminant meat that cost the same or less and taste as good or better but whose production results in far lower methane emissions. That is exactly the point of alternative proteins, such as plant-based meats and dairy products, cultivated meat, and precision fermentation products.

Unlike conventional plant-based proteins like tofu and seitan or insect-based foods, alternative protein products aim to give consumers the experience of eating conventional meat without the environmental and other downsides associated with livestock production. Life cycle analyses show that some alternative proteins produce as little as 8% of the greenhouse gas emissions generated by their animal-derived competitors.[31] That means that, if alternative proteins were to become as appealing to consumers as ruminant meat, enteric methane emissions could fall even as consumers continue to get what they want, just as the shift from internal combustion to electric vehicles is decreasing transportation emissions without requiring major changes in consumer behavior. In fact, one recent modeling effort found that alternative proteins have greater potential to mitigate methane than any other food system innovation: they could reduce methane emissions by as much as 1.8 Gt CO2e per year by 2050, halving food system methane emissions.[32]

Multiple lines of evidence suggest that when alternative proteins can compete effectively on cost and taste, consumers will choose these products over conventional animal meat at high enough rates to achieve a meaningful reduction in methane emissions. For example:

- We have seen similar changes in consumer behavior in the recent past. Over the past several decades, we have seen significant declines in beef consumption in North America, Western Europe, Australia, and New Zealand.[33] According to an analysis funded by the beef industry this trend is largely explained by two factors in the United States: falling chicken and pork prices and rising consumer concern about adverse health impacts of red meat consumption.[34] This trend suggests consumers are willing to forego ruminant meat when presented with an affordable and sufficiently similar alternative, particularly when they view the alternative as being superior in some way.

- Recent modelling shows consumption of conventional animal meat will fall in proportion to the cost of alternative proteins. The decline will be greater in scenarios where these products are seen as having health, nutrition, sustainability, or other advantages over conventional animal meat.[35]

- Consumer survey data suggests consumers will choose alternative proteins at higher rates if prices fall and taste improves, just as people are shifting toward electric vehicles as prices fall and battery range improves.[36]

As these considerations illustrate, alternative proteins have an important role to play in closing the methane emissions gap left by production-side strategies to decrease methane intensity of ruminant meat and milk.

Still, alternative proteins have a long way to go before they can realize their potential as a methane mitigation solution. Dissatisfaction with the taste and texture of these products is the main reason consumers decide not to buy them again after trying the product.[37] At the same time, the products that best satisfy consumers—the Beyond and Impossible burgers—currently cost about twice as much as traditional ground beef. Significant investments in R&D and commercialization measures are needed to help these products compete on cost and taste with conventional animal products. Given the mitigation potential of alternative proteins, such investment is an indispensable methane mitigation solution for the food and agriculture sector.

IV. Co-benefits of Alternative Protein Innovation

In addition to significantly reducing methane emissions, alternative protein innovation could deliver several other important environmental and social benefits, including reductions in deforestation, air and water pollution, biodiversity losses, land demand for food, food insecurity, pandemic risk, and antibiotic resistance. Growth in the alternative protein industry would also create jobs and have other notable economic benefits.[38]

Significant non-climate environmental benefits

Production of conventional animal meat is the number one driver of tropical deforestation—itself a major source of greenhouse gas emissions—as well as a major contributor to air and water pollution and biodiversity losses.[39] In addition, producing conventional meat requires vastly more land than other food.[40] Notably, all of these external costs of conventional meat production—currently at levels worthy of significant concern and attention—will only become more severe as meat production globally continues to rise inexorably through 2050.

Consequently, investments aimed at increasing the consumer appeal of alternative proteins, particularly those intended to mimic ruminant meat, could deliver significant environmental benefits, including:

- **Reduced deforestation and biodiversity loss**. Because conventional meat production requires so much land for grazing and feed production, alternative protein innovation could significantly reduce the demand for land that drives both the deforestation and biodiversity losses.[41]

- **More and higher quality water.** Nitrogen from animal manure and the fertilizer used on pastures and to grow feed pollutes rivers, lakes, and oceans, leading to eutrophication, harmful algal blooms, and dead zones. In addition, conventional meat production is highly water-intensive.[42]

- **Improved air quality.** While air pollution data is only available for cultivated meat (20-94% lower particulate matter pollution than conventional meat) and will vary somewhat depending on the energy source used, in general, APs should produce far less air pollution than conventional meat, given that the pollution associated with the latter largely stems from manure.[43]

Table 1. Percentage reduction in environmental impact of APs compared to conventional animal meat.

Eating this plant-based meat	*Instead of this conventional meat*		*Reduces this environmental impact by this much*		
		Land use m^2-y/kg	Greenhouse gas emissions kg-CO_2-eq/kg	Water use L/kg	Aquatic eutrophication potential g-PO_4^{3}-eq/kg
Impossible Burger 2.0	Beef burger*	96%	89%	87%	91%
Beyond Burger	Beef burger**	-	89%	99%	-
Grillers Original Burger	Beef burger	93%	85%	95%	77%
Spicy Black Bean Burger	Beef burger*	97%	89%	96%	76%
Roaster Garlic & Quinoa Burger	Beef burger*	93%	88%	98%	73%
Grillers Crumbles	Ground beef**	99%	90%	96%	-
Original Sausage Patties	Pork sausage patties*	47%	30%	81%	51%
Original Chik Patties	Breaded chicken patties*	84%	36%	72%	75%

*Note: Adapted from The Good Food Institute's "Plant-based Meat for a Growing World," available here: https://gfi.org/wp-content/uploads/2021/02/GFI-Plant-Based-Meat-Fact-Sheet_Environmental-Comparison.pdf. This table represents the results of all English-language comparative life cycle assessments of plant-based meat conducted as of May 1, 2019. Because each study differs slightly in its methodology, the results from different studies cannot be precisely compared. *Sold frozen. **Sold fresh. Impact reductions are calculated as follows: (impact of conventional meat – impact of plant-based meat)/(impact of conventional meat).*

Strengthening food security

In addition to these various environmental co-benefits, alternative protein innovation could also have significant food security benefits.[44] In part this is simply a function of APs' much lower greenhouse gas emissions compared to conventional animal meat. Because climate change itself can lead to disruptions in the food supply through extreme weather events, changing rainfall patterns, and other challenges, anything that helps to get emissions to safe levels also helps to increase food security. But there are three additional factors at play in this case: the relatively lower vulnerability to localized shocks and greater adaptability of AP supply chains, the resilience benefits of diversifying protein sources, and the extreme resource-inefficiency of animal foods.

The global supply chain impacts of COVID-19 have made abundantly clear that our food system is fragile and prone to disruption. However, animal production in particular has two features that make it especially vulnerable to breakdown. First, because it requires particular geographies and climates, animal protein production tends toward a degree of spatial concentration that exacerbates its vulnerability to localized disruptions such as natural disasters when compared to other, less spatially concentrated supply chains. Second, the timeline from the first planting of feed crops to the final distribution to supermarkets is long and hard to adjust mid-stream, making short-term adjustments difficult. By contrast, alternative proteins can be produced almost anywhere, enabling great geographic dispersal, and involves shorter timelines that make it far easier to adapt their supply chains to unexpected changes than those for animal products.

Similarly, alternative proteins help to make food systems more resilient to shocks by increasing the diversity of available protein sources. Because alternative protein supply chains are so different from those for many other protein sources, they are less likely to be impacted by disruptions affecting other protein sources. As a result, increases in alternative protein availability and affordability can help ensure that consumers continue to have access to high-quality protein sources when they otherwise would not.

Finally, animals are highly inefficient converters of feed to food. Only about 2% of the calories fed to a cow as feed or forage are converted to beef; for pigs and chickens, the corresponding figures are 8.6% and 13%, respectively.[45] Consequently, far more grains and other feed crops must be produced and more land used to support dietary patterns high in animal products than for more plant-based diets.[46] In fact, only around half the world's cereals and about a fifth of its soy is used for human food, with about a third of cereals and nearly three quarters of soy used to feed animals.[47] If consumers begin to choose alternative proteins over conventional meat at high enough rates, demand for these and other human-edible feed crops would fall significantly, freeing up more food for humans and, according to one modeling effort, lowering average crop prices more than 12% by 2050.[48]

Protecting public health

AP innovation could also help to reduce public health risks related to pandemics, wildlife-derived diseases, and antimicrobial resistance. *Preventing the Next Pandemic*, a report published by the International Livestock Research Institute (ILRI), CGIAR, and the United Nations Environment Programme (UNEP) named increasing demand for meat and intensive livestock production as two of the seven major anthropogenic drivers of zoonotic disease emergence.[49] In addition, with around 65% of all medically relevant antibiotics sold being used on livestock, livestock production contributes to the emergence of antibiotic-resistant superbugs, which some estimates suggest could lead to as many as 10 million deaths annually by 2050.[50] By contrast, since alternative protein production does not using large quantities of antibiotics on large numbers of genetically similar animals held together in close quarters, it does not carry these same risks.

Bolstering the global economy

Once alternative protein production achieves sufficient scale, the industry stands to create millions of jobs and significantly increase gross value added (GVA). According to one recent estimate, APs could lead to the creation of more than 53 million jobs by 2040 and as many as 83 million by 2050, some of them specialized technical skills.[51] In addition, GVA could increase from about $29 billion today to as much as $740 billion in 2040 and $1.1 trillion by 2050.[52] Notably, alternative proteins account for 70% of the jobs expected from innovations to address food system methane emissions and 98% of the expected increase in GVA.[53]

V. Recommendations for Policymakers

Taken together, these considerations make clear that alternative protein innovation aimed at achieving price and taste parity with conventional animal meat is a key strategy, not just for reducing methane emissions, but also for addressing a range of other environmental and social challenges. To advance this promising mitigation technology, Methane Pledge participants should pursue three guiding strategies:

1. Foster innovation in alternative proteins
2. Mainstream alternative proteins within international climate processes.
3. Engage in international cooperation.

The remainder of this brief offers eight specific recommendations to guide policymakers in implementing these strategies.

Strategy 1: Foster innovation to improve taste and texture while reducing costs.

RECOMMENDATION 1: DRIVE DOMESTIC GROWTH OF THE ALTERNATIVE PROTEIN INDUSTRY THROUGH TARGETED INDUSTRIAL POLICY MEASURES.

As with electric vehicles, wind turbines, and solar panels, market forces alone will not be enough to grow the alternative protein industry rapidly enough to align emissions with international climate goals. Governments can help speed this process by enacting targeted policy measures to de-risk investments in alternative protein production as a means of crowding in needed private capital.

Government support could take the following forms, among others:

- Dedicated funding for open-access research and development
- Loan guarantees
- Advance market commitments for alternative protein products based on quality and cost targets
- Expanding agricultural support programs to provide more resources for alternative protein inputs
- Tax incentives for alternative protein companies
- Workforce development programs
- Funding for demonstration projects

In addition, governments should collaborate to create export markets for alternative proteins. These efforts would complement efforts to increase domestic production of APs by increasing demand for domestic products abroad. Promising investment destinations for export market development include many Asian countries, which may currently lack the cold chains that many alternative protein products require.

RECOMMENDATION 2: JOIN OTHER METHANE PLEDGE COUNTRIES IN A NON-BINDING COMMITMENT TO INCREASE GLOBAL PUBLIC FUNDING FOR ALTERNATIVE PROTEIN INNOVATION TO $10.1 BILLION PER YEAR.

In 2020, total private sector investment in alternative proteins reached $3.1 billion, while public sector investment was negligible.[54] This level of investment pales in comparison to public and private investment in clean energy—upwards of $1.4 trillion in 2022.[55] More importantly, it falls far short of the amount required to realize the full environmental and social benefits of alternative proteins. The level needed for global public sector investment alone is estimated at $10.1 billion per year ($4.4b on RD&D and $5.7b on commercialization).[56] Methane Pledge participants should pledge to meet this challenge, both through new public funding and by taking steps to crowd in additional private financing.

RECOMMENDATION 3: CREATE A GLOBAL NETWORK OF RESEARCH CENTERS TO ADVANCE ALTERNATIVE PROTEIN INNOVATION PRE-COMPETITIVELY.

Right now, many companies are working independently to make plant-based and cultivated meat taste better and cost less. Much of the work is duplicative, and almost all of it aims to benefit one company exclusively—the company doing the work. To accelerate the pace of innovation, countries should work together to establish a global network of alternative protein research centers focused on catalyzing scientific advances to speed the path toward sensory, price, and scale parity with conventional meat. Researchers' findings could be made publicly available through a central clearinghouse so that, rather than advancing the work of a single company, breakthroughs can raise the floor for the entire field. Either CGIAR or a new international body created specifically for this purpose could serve as the secretariat for this network, helping to coordinate efforts, identify key areas in need of further study, and disseminate research.

Strategy 2: Mainstream alternative proteins within international climate governance processes.

RECOMMENDATION 4: COMMIT TO EMBEDDING ALTERNATIVE PROTEINS IN NATIONAL CLIMATE CHANGE IMPLEMENTATION PLANS (NDCs, or Nationally Determined Contributions), including in food innovation and agriculture-related climate adaptation and mitigation strategies.

RECOMMENDATION 5: ENDORSE A NON-BINDING, QUANTITATIVE, TIME-BOUND GLOBAL GOAL FOR REDUCING ENTERIC METHANE EMISSIONS GLOBALLY.

Though the United States recently introduced a food and agriculture pathway for Methane Pledge participants, to date there has been no explicit focus within that initiative on the single largest source of methane emissions from food and agriculture, enteric fermentation. A quantitative, time-bound goal would help focus participants' attention and energies on mitigation strategies and solutions that would address these emissions, including alternative proteins, as well as to convey a general sense of the urgency of doing so.

Strategy 3: Engage in international cooperation to advance alternative proteins.

RECOMMENDATION 6: CREATE A DIPLOMATIC FORUM FOR INTERGOVERNMENTAL DIALOGUE ON ADVANCING ALTERNATIVE PROTEINS.

Similar to the Clean Energy Ministerial and Mission Innovation Partnership for encouraging clean energy and battery development, this forum could allow first-mover countries the space to put forward ideas and investments to advance and champion alternative proteins.

RECOMMENDATION 7: DEVELOP BILATERAL AND PLURILATERAL PROGRAMS ON ALTERNATIVE PROTEINS VIA DIPLOMATIC OR FOREIGN ASSISTANCE CHANNELS.

For example, countries could explore alternative protein-focused partnerships along the lines of the Just Energy Transition Partnership model the United States, Japan, and other countries have been developing with Indonesia and South Africa.

RECOMMENDATION 8: SIGN ONTO AND COMMIT TO MEETING PRIORITY INTERNATIONAL ACTIONS DEVELOPED COLLABORATIVELY BY COUNTRY SIGNATORIES TO THE AGRICULTURE BREAKTHROUGH AND INFORMED BY THE BREAKTHROUGH AGENDA REPORT 2022.[57]

In particular, countries should prioritize delivering higher levels of investment in agricultural research, development and demonstration to generate progress in protein innovation and developing standards for monitoring and reporting on the state of natural resources and the geographical extent of agriculture.[58]

[1] United Nations Environment Programme and Climate and Clean Air Coalition, *Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions* (henceforth GMA), (Nairobi: United Nations Environment Programme, 2021), p. 11. According to the IPCC, methane is 28 times more potent than carbon dioxide over a 100-year period and 84 times more potent over a 20-year period. See Myhre, G., D. Shindell, F.-M. Bréon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J.-F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura and H. Zhang, "2013: Anthropogenic and Natural Radiative Forcing," in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley, (Cambridge: Cambridge University Press, 2013), p. 731.
[2] GMA, p. 20.
[3] Ibid.
[4] Ibid.
[5] GMA, p. 11.
[6] Ocko, et al., "Acting rapidly to deploy readily available methane mitigation measures by sector can immediately slow global warming," *Environmental Research Letters* 16, no. 054042 (2021), https://doi.org/10.1088/1748-9326/abf9c8. For a general overview of the relative importance of methane as a greenhouse gas, its sources, climate interactions, and mitigation strategies, see, in addition to the GMA, Reay, et al., "Methane and Global Environmental Change," *Annual Review of Environment and Resources* 43 (2018): 165-192, https://doi.org/10.1146/annurev-environ-102017-030154.
[7] GMA, p. 28.
[8] Ibid.; cf. Global Methane Hub and ClimateWorks Foundation, "Global Innovation Needs Assessments: Food System Methane," Technical Report, April 2023, https://www.climateworks.org/ginas-methane/, p. 10.
[9] Searchinger, et al., "Opportunities to Reduce Methane Emissions from Global Agriculture," November 2021, https://searchinger.princeton.edu/publications/opportunities-reducemethane-emissions-fromglobal-agriculture.
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[11] See Joshua D. McBee, "Reducing Methane Emissions from Food and Agriculture: Opportunities for U.S. Leadership," Climate Advisers, October 6, 2022, https://www.climateadvisers.org/wp-content/uploads/2022/10/Climate-Advisers-Reducing-Methane-Emissions-from-Food-and-Agriculture.pdf; Searchinger, et al., "Opportunities to Reduce Methane Emissions from Global Agriculture"; Global Methane Hub and ClimateWorks Foundation, "Global Innovation Needs Assessments: Food System Methane"; and Joseph W. McFadden, "Cow Burps Have a Big Climate Impact. Solving That is Harder than You'd Think," *Time*, February 1, 2023, https://time.com/6251162/cow-burps-climate-impact-methane-emissions/.
[12] Ivanovich, et al., "Future Warming from Global Food Consumption." As a matter of fact the figure in the text is likely too high, since the 0.2 degrees Celsius of reduced future warming these researchers found was for measures to increase the productivity, not just of ruminant meat, but also of dairy, non-ruminant meat, and rice.
[13] See, in addition to Ivanovich et al., "Future Warming from Global Food Consumption," Arndt, et al., "Full adoption of the most effective strategies to mitigate methane emissions by ruminants can help meet the 1.5 °C target by 2030 but not 2050," Clark, et al., "Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets"; J. Poore and T. Nemecek, *Science* 360, no. 6392 (2018): 987-992, https://doi.org/10.1126/science.aaq0216; and Ciniro Costa, Jr., et al., "Roadmap for achieving net-zero emissions in global food systems by 2050," *Scientific Reports* 12, article no. 15064 (2022), https://doi.org/10.1038/s41598-022-18601-1.
[14] See Global Methane Hub and ClimateWorks Foundation, "Global Innovation Needs Assessments: Food System Methane," Technical Report, Table 4.3 and p. 44, discussed in Section 3 below.
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[17] Ibid., p. 20.
[18] Ibid.
[19] Ibid.
[20] GMA, p. 11.
[21] Ocko, et al., "Acting rapidly to deploy readily available methane mitigation measures by sector can immediately slow global warming."
[22] GMA, p. 28.
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[25] Ivanovich, et al., "Future Warming from Global Food Consumption."
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[29] Ivanovich, et al., "Future Warming from Global Food Consumption."
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[51] "Global Innovation Needs Assessments: Food System Methane," Technical Report, pp. 33-34.
[52] UK Foreign, Commonwealth and Development Office and ClimateWorks Foundation, "Global Innovation Needs Assessments: Protein Diversity," p. 16. Note that the GVA numbers in the more recent Global Innovation Needs Assessments report on food system methane emissions are a bit lower. See "Global Innovation Needs Assessments: Food System Methane," Technical Report, pp. 33-34.
[53] "Global Innovation Needs Assessments: Food System Methane," Technical Report, p. 6.
[54] "Global Innovation Needs Assessments: Protein Diversity," p. 18.
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[58] Many thanks to Catherine Ivanovich and Claudia Arndt for helpful discussion of their and their colleagues' work, as well as to colleagues at Climate Advisers and the Good Food Institute for helpful discussion.

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DECOUPLING METHANE EMISSIONS FROM MEAT WITH ALTERNATIVE PROTEINS: RECOMMENDATIONS FOR METHANE PLEDGE PARTICIPANTS

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