Inform, Invest, Incentivize: A Menu-Driven Approach to Reduce the Environmental Impact of Meat in the United States

Paper first received: 18 February 2024; Accepted: 03 August 2024; Published in final form: 12 January 2025
https://doi.org/10.48416/ijsaf.v30i2.601

Kacey LABONTE,[1,3] Adela MUNSON,[2,3] and Donald ROSE[3]

Abstract

Human food systems, especially livestock production, contribute significantly to environmental degradation. The meat industry has an outsized political influence in the United States (US) and in other countries, which makes system-level changes, such as government policies to reduce meat production and consumption, difficult to enact. In this perspective article, we propose an all-of-society approach, outlining potential actions, not just by government but also by industry and the non-profit sector, to promote sustainable diets through reduced and less impactful meat consumption. Given current political realities in the US, we argue that government incentives such as subsidies are more likely to be implemented than disincentives such as taxes. The food industry has a role to play in developing meat alternatives, in promoting new dishes focused on plant protein foods, and in reducing the impact of current meat production. The non-profit sector can contribute research and advocacy to study and promote relevant actions. In articulating this approach, we seek to enhance dialogue between food system stakeholders and to increase actions across various sectors. To this end, we provide concrete examples of such actions, organised into three broad categories, which: (1) inform the public about the environmental impacts of foods; (2) invest in alternative meats and plant protein foods; and (3) incentivise consumers, producers, and suppliers to reduce their impact by consuming, producing, and supplying more of these alternatives. We argue that this approach of simultaneous synergistic actions could ultimately lead to broader system-level change.

[1] University of Vermont, USA
[2] Policy and Research Group in New Orelans, USA
[3] Tulane University, USA

Corresponding author: Daniel Rose, diego@tulane.edu

Bibliographical notes

Kacey LaBonte holds a MPH in Nutrition from Tulane University and a BA in Global Studies from Colby College. She is currently working on her doctorate in Food Systems at the University of Vermont.

Adela Munson holds a MPH in Nutrition from Tulane University and a BA in Global Studies from University of North Carolina, Chapel Hill. She currently works as an analyst for the Policy and Research Group in New Orleans.

Donald (Diego) Rose is the Nutrition Program Director and Professor at Tulane University.

Introduction

Human food systems contribute substantially to environmental degradation, accounting for a third of all human-caused greenhouse gas emissions (GHGE) (Crippa, 2021). The largest share of this impact comes from the production side of agriculture and includes land use and land use changes needed to support agriculture's expansion. Agricultural production is also responsible for about 70% of global freshwater withdrawals (UNESCO, 2020) and has caused serious problems of land deterioration (FAO, 2011). Within agriculture, the livestock sector has a particularly large footprint. GHGE associated with the meat and dairy sector account for 14.5% of global emissions (Gerber et al., 2013). A more recent analysis found that meat and dairy will be responsible for about 60% of food system impacts on global warming through 2030 (Ivanovich, 2023).

The importance of reducing the environmental impact of meat production by reducing its consumption has been articulated in several studies and international reports (Dumas et al., 2022; Breewood and Garnett, 2023). The EAT-Lancet Commission report has developed dietary guidelines to support health and sustainability, which emphasise plant protein consumption and include meat consumption targets that are much lower than current levels in high-income countries (Willett et al., 2019). In its mitigation of climate change report, the United Nations Intergovernmental Panel on Climate Change (IPCC) called for an increased share of plant-based protein sources as a dietary shift that could help mitigate food system emissions (IPCC, 2019). Reducing food system emissions is essential for achieving our climate targets, and a key aspect of this is adopting a plant-rich diet to reduce meat and dairy consumption (Hedenus et al., 2014; Clark et al., 2020; Agyemang, 2022). Much of the discussion surrounding reduction in meat consumption has focused on beef, since its impact on emissions is eight to ten times that of chicken and other meats from non-ruminant animals (Heller et al., 2018; Poore and Nemecek, 2018).

The United States (US) is the world's largest beef producer (Brower, 2022; Cook, 2023); in 2023 it produced 27 billion pounds of commercial beef (USDA ERS, 2024), an average of 58 pounds of beef consumed per capita. Of the total produced, 3 billion pounds were exported and valued at 9.3 billion US dollars (USDA ERS, 2024). The 'cattle-beef' complex, that supports this production, has developed in the US over the past 150 years and has been shaped by technological innovations such as railroads and refrigeration, as well as by capital investments and government policies (Specht, 2019). Throughout this time, industry influence in policymaking has strengthened, supported by a consumer base that prizes inexpensive beef. This has resulted in a policy bottleneck in which potentially effective sustainable dietary policies to reduce beef's footprint are politically unpopular and difficult to enact in the US and elsewhere (Dutkiewicz, 2021).

This paper outlines an approach that supports the reduction of meat production and its impact in the US with four defining characteristics. First, the approach encompasses diverse solutions to reduce meat's current impact, by reducing both its consumption and the impact of what gets consumed. This is achieved either by replacing meat with plant-based alternatives or lower-impact meats, or by reimagining consumer meals. Second, it focuses government policy on incentives, like subsidies, rather than disincentives, like taxes. Third, it is an all-of-society approach involving not just government, but also the food industry (including meat suppliers), the non-profit sector, and consumers. Fourth, it deliberately seeks to promote synergies and positive feedback loops between these actors, to accelerate transformation. In articulating this approach, we seek to enhance dialogue between food system stakeholders and to increase actions by those in local, state, and federal governments, the food industry, non-profit organisations, advocacy groups, and research centres. To promote this dialogue we provide examples throughout the paper of existing policies and actions consistent with this approach. We refer to this as a menu-driven approach because of the diversity of actions that can be taken by different food system actors and because the optimum choice of such actions will vary, depending on their specific political, cultural, and economic context. The following sections describe each of the components of this approach.

Reduce, Replace, Re-imagine: Consumer Actions to Reduce Impacts

Consumers, through their purchase behaviours, can send signals back up the supply chain, and upstream actors, including retailers, distributers, manufacturers, and producers, can respond by modifying production and distribution behaviours to meet consumer demand (IOM, 2015). What can consumers do to reduce the overall impact of their food choices on greenhouse gas emissions? Meat is the largest share of this dietary carbon footprint (Heller et al., 2018), so it is an obvious place to begin.

Eating less meat can be a relatively easy way to lower impact because it does not require giving it up entirely. Reduction can refer to either the frequency or the amount consumed. Meatless Mondays were developed with the former in mind (The Monday Campaigns, 2003) and have been studied more recently in various contexts (Sheldon, 2021; Rayala, 2022). On any given day, meat, particularly beef, is the most environmentally impactful item that Americans consume (Rose et al., 2022). Reducing the amount consumed would clearly reduce their overall dietary carbon footprint, as evidenced in simulated substitutions in which reducing the meat consumed per day by one quarter resulted in an average decrease in dietary footprint of 12% (Willits-Smith et al., 2020).

Assuming individuals are at a steady state in their diets with respect to energy intake, reducing the consumption of specific foods will be accomplished by replacing them with something else. In the above example, the reduction of meat was achieved by substitution with plant-based protein foods of the same energy value. Rose, Grummons, and colleagues (2022, 2023) have studied single-item substitutions – replacing just one item in one meal a day – and found that the replacement of beef with poultry resulted in an average decrease in the dietary carbon footprint among US consumers of about 50%. Substituting with plant-based protein foods would result in a larger decrease, while at the same time reducing other environmental impacts and addressing concerns about animal welfare. Alternative meats, such as those developed by Beyond Meat and Impossible Foods, are examples of other foods that can replace currently consumed meats (Capritto, 2019).

These calculations, as well as the rest of our discussion around consumer changes, are based on the idea of substitution with nutritionally similar foods. According to the Dietary Guidelines for Americans, the 'protein foods' group includes beef, pork, other meats, poultry, eggs, fish, as well as plant proteins such as dried beans and peas, nuts, and seeds (USDA & DHHS, 2020). Thus, we argue for substitutions that reduce environmental impacts by consuming less beef, but that preserve the basic nutritional quality of the diet by selections from the same nutritional food group. The studies cited above simulated these types of substitution and showed that diet quality actually improved with substitutions for beef (Rose, 2022; Grummons, 2023).

A key aspect of reducing meat intake is shifting cultural norms about the concept of a meal. The traditional US steak and potatoes dinner could be reimagined as a much more interesting mixed-dish plate, in which meats are used in sauces that complement the flavours of a vegetable dish (FoodPrint, 2023). There are rich culinary traditions throughout the world that provide such examples, many of which are already employed in the US (Rogers, 2020; Tekiner, 2021). These traditions can also be used to promote plant-based main dishes that are not meat analogues, but are hearty, flavourful, and nutritious dishes in their own right.

It is likely that some consumers will continue to eat beef, regardless of which health, environmental, or animal welfare reason is raised. This is because changing consumer behaviour is very difficult. Although not related to dietary behaviours, this difficulty has been well-documented in the tobacco control literature where even after 60 years of anti-smoking campaigns – from information, persuasion, and changing social norms to taxes and anti-smoking ordinances – state-level adult smoking rates still range from 8-24% in the US (World Population Review, 2023). Acknowledging this, it would be wise to focus on reducing the impact of beef production. For example, intensification in the US beef industry has reduced its carbon footprint since the 1970s due to improvements in productivity and efficiency (Capper, 2011), and certainly additional strides can be made (Hyland et al., 2017). However, intensification is problematic, in part because of the overall increase

in production, but also for both health and animal welfare concerns (Bernstein and Dutkiewicz, 2021). Given that it produces cheaper beef, intensification is likely to increase rather than decrease its consumption. Trewern and colleagues (2022) have studied a 'less and better meat' approach to reduce consumption, through regenerative agricultural production of higher quality and less environmentally impactful beef. This niche approach, and pathways to promote it, will be important going forward.

Throughout the above section we have discussed changes that individual consumers can make. We began our approach with individuals because many people are frustrated with the slow pace of government action on climate change and want to take action themselves; changing eating patterns is a personal and direct type of action. However, individuals do not operate in isolation. They are part of a social structure that influences their behaviour, as do elements of larger economic and political systems, including economic agents, such as corporations, and government policies, which we discuss next.

Government Policies to Inform, Invest, Incentivise: Carrot vs. Stick

Can government policy influence food system actors, such as consumers, discussed in the previous section? In 2007, the Nuffield Council on Bioethics published a seminal report on government policy interventions to promote public health (Nuffield, 2007). The report outlined policies and interventions that can affect people's choices on a continuum of least to most intrusive. For example, providing information to consumers is not very intrusive, whereas eliminating choice is the most intrusive.

In the US, resistance to government intervention is often a rallying cry for those who oppose interventions in the field of public health. This has been seen in issues as diverse as efforts to reduce obesity (Véliz et al., 2019), the ban on trans fats (Resnik, 2010), and mask-wearing regulations (Bazzi et al., 2021). Anti-government advocates are particularly bothered by actions that seek to guide consumers using disincentives (e.g. taxes), restrictions, or elimination of choices; in other words, the extreme end of the Nuffield continuum of policies. Given this resistance and the polarising national political climate in the US, these types of policy are not likely to be implemented at the federal level (Dutkiewicz, 2021). This is particularly the case for restrictions on meat, which has been termed the third rail of American climate politics and which has provoked strong responses from conservative media, activists, and lawmakers, even when such restrictions are not being contemplated (Atkin, 2019; Smith, 2021; Cunningham, 2022).

Accordingly, in this paper we focus on positive incentives, such as provision of information or subsidies, which are more realistic for implementation in the current US political climate. We organise potential interventions using the metaphor of a menu, and we include actions across several sectors, consolidated into three broad categories: inform, invest, and incentivise. We use incentivise in the broadest sense of the word, that is, to encourage, lead or make someone want to do something. See Table 1 for generic examples of such actions. Recognising the importance of the earlier framing of government policy interventions in the field of public health, we also provide a crosswalk between our menu topics and the policy continuum of the Nuffield group, as well as others (see Supplementary Table 1 at the end of our paper).

Specific examples of government policies to reduce the impact of meat using our typology of inform-invest-incentivise are given in Table 2 or are mentioned in the text below. Governments can inform individuals about the environmental impacts of different food items through dietary guidance and food labelling. For example, the Netherlands included sustainability in their government dietary guidelines, a publication that describes the health benefits of food choices (Brink, 2019). Similar work has been or could be undertaken in many countries (Rose, 2019). Food labelling on environmental impacts is another way to inform consumers, and governments could provide guidance to industry. An example of local government action is New York City (NYC), which partnered with the American College of Lifestyle Medicine to roll out the largest lifestyle medicine training

in the world, aiming to educate up to 200,000 NYC healthcare practitioners in six pillars of lifestyle health, including in plant-based eating patterns (City of New York, 2022).

Table 1. Generic menu examples to accelerate the transition to lower meat consumption and lower impacts, by type of intervention

Type of intervention	Example Actions	Actors and Instruments
Inform	Include sustainability in DGA	Government publications
	Food labelling	Industry actions and government regulations
	Menu labelling	
	Information campaigns, including new recipes	Government, industry, non-profits
Invest	Alternative plant-based meat development	Increased R&D funding from government, industry
	Lab-cultivated meats	
	Reduced carbon beef	
	Plant-protein farming	
Incentivise	Increase availability of plant-protein alternatives	Government subsidies, institutional food services, including schools, universities, hospitals, prisons, and the governing bodies that regulate these services
	Develop tastier alternative protein recipes	
	Make alternative proteins the default	
	Provide discounts for plant-based choices	
	Transition to Meatless Mondays	

Table 2. Examples of policies for governments

Type of intervention	Federal	State	Local
Inform	Canada's 2018 Dietary Guidelines for Health Professionals and Policy Makers advocates for increased consumption of plant-based protein (Government of Canada, 2019-b)	California free webinar for school food service staff on topic of plant-based menu planning (CDE, 2018)	NYC practitioner lifestyle training on topics such as plant-based eating (City of New York, 2022)
Invest	Canadian government invests $153M in plant-based protein supercluster (Government of Canada, 2019-a)	California invests $5 million in alternative protein research at three state universities (Budget Act of 2022, 2021)	Pittsburgh Public Schools passed the Good Food Purchasing Policy, a local procurement model that supports environmental sustainability (GFPP, n.d.)
Incentivise	US House passed a bill requiring the US navy to pilot a program for offering plant-based protein options at bases for Navy members (National Defense Authorization Act, 2022) USDA GusNIP and Produce Rx program to provide matching funds for additional fruit and vegetable purchases (Nutrition Incentive Hub, n.d.)	AR Grown Grant pilot program for farmers to produce more F&V (Arkansas Department of Agriculture, 2022)	NYC Plant Powered Fridays in schools make plant-based meal default choice (NYC DOE, 2023) DC's Healthy Students Amendment Act of 2018 encourages plant-based meals (DC Law Library, 2019)

Governments can invest in research, development, and/or support for the mass production and distribution of meat alternatives (Smith et al., 2021). For example, the Canadian government invested $153 million in a plant-based protein supercluster, an initiative to connect companies, non-profits, and academic institutions to bolster the development of plant-based products (Government of Canada, 2019a). In the US, a bill called the Peas, Legumes, and Nuts Today (PLANT) Act was introduced in July 2023 in Congress to support farmers, food companies, and research focused on plant-based food production (McGovern, 2023). The bill was initially referred to the House Committee on Agriculture and a year later has yet to be considered (PLANT Act, 2023). Additional investment in plant protein foods could lead to better and less expensive food products and ultimately, over the long term, influence consumer demand.

Governments can also incentivise, promoting meat alternatives directly by ensuring their availability at government facilities, as in the US Navy's pilot programme to offer plant-based protein options at forward operating bases (National Defense Authorization Act, 2022). In the State of California, legislation to ensure the availability of plant-based meal options was passed in 2018, requiring all state institutions, including hospitals and prisons, to offer at least one plant-based option per served meal (California State Senate, 2018). Beyond just ensuring availability, governments can further promote a shift to plant-based foods with subsidies. For example, in the US, the Gus Schumacher Nutrition Incentive Program (GusNIP) provides grants to local organisations that aim to increase fruit and vegetable purchases by low-income consumers, by providing additional funding for this (Nutrition Incentive Hub, n.d.). Although this has not been oriented around plant-based protein foods, or alternative meats, it certainly could be. In addition to incentivising consumption of plant protein foods, government can incentivise their production. The PLANT Act, mentioned above, seeks to invest in research and development of such products, but also to incentivise their production through loans and grants (PLANT Act, 2023).

The above section has described examples of government policies that might influence food system actors. However, the social, economic, and political forces that influence which policies get implemented is crucially important. Corporate actors have used political influence, for example through lobbying, to promote their goals (Mialon et al., 2015). In addition to political polarisation and the general dysfunction of the US Congress, agricultural committees are often dominated by legislators that come from rural and conservative states. The interaction of political conservativism with industry influence has contributed to the dominance of animal food policies in major farm legislation in the US (Sewell, 2020). At a state level, this can be seen in a spate of recently introduced bills that ban the production and/or sale of cell-cultured meat (Mattox, 2024), all with the intent of protecting livestock sales. Thus, reducing subsidies to animal agriculture, let alone taxing their production, will be difficult (Vallone and Lambin, 2023). In this environment, increases in subsidies to plant-based foods are more likely to be accepted. This is the hope for the PLANT Act, yet it has not moved since its introduction, likely because of the conservative-controlled US House of Representatives.

An Approach for All of Society's Sectors

Food system change requires much more than government action, which is why we, like other proponents of a transformation, propose an all-of-society approach (Rust et al., 2020; Dutkiewicz 2021; Espinosa-Marròn et al., 2022). Food companies are already innovating in the alternative meat space, both in plant-based options such as Beyond Meat or Impossible Meat, (Beyond Meat, 2023; Impossible Foods, Inc., 2023), and in cell-cultured, or lab-grown, meat (Upside Foods, 2023; Aleph Farms, 2021). These actions can be reinforced by other supply chain actors, such as restaurants or retailers that promote these products (Table 3), and supported by government actions as mentioned above.

Table 3. Examples of actions for industry

Type of intervention	Trad Meat Producer	Alt Meat Producer	Restaurant / Cafeteria	Grocery
Inform	Voluntary restriction of advertisements aimed at children	Beyond Meat sustainability course for students (Beyond Meat, 2020)	Just Salad puts 'carbon labels' on menus to indicate carbon footprint of each meal (Just Salad, 2022)	Lucky Supermarket's 'Fall in Love with Plant Based' education campaign (PBFA, 2018)
Invest	Tyson Foods Launches Plant-Based Meat (Raised & Rooted, 2022) Elmhurst Dairy (now Elmhurst Milked) completely transitioned from cow- to plant-based milks (Elmhurst, 2023)	Beyond Meat partners with restaurant chains to increase plant-based supply (Reinicke, 2019)	Foss dining hall at Colby College sources locally to increase vegan and vegetarian food options (Colby College, n.d.)	Kroger supermarket announces new Simple Truth plant-based protein line (The Kroger Co. 2020)
Incentivise	Tyson Foods offers $15/case rebate on plant-based pepperoni (Tyson Foods, 2022)	Impossible announced cutting suggested prices by 20% for grocery stores and supermarkets to get closer to their goal of price parity with beef (Woodside, 2021)	Hong Kong's Pay-A-Vegan app gives a $1 coupon per vegan meal for use at participating restaurants (PayVegan Hong Kong Limited, 2021)	NYC Fine Fare independent grocery store "Get the Good Stuff" SNAP incentive program (WGB, 2019)

Going forward, it will be important to monitor the impacts of alternative proteins, especially lab-grown meats, as some have argued that they require similar energy consumption as does traditional meat production (Guthman & Biltekoff, 2020). This technology is relatively new, so there is potential for the alternative protein sector to improve their practices as investment and demand grow. A lifecycle assessment published by the Good Food Institute (2021) foresees that by 2030, if clean energy is used, cultivated meat would have a 92% lower footprint than traditional beef.

Restaurants and cafeterias can inform consumers through eco-labelling of menu items. A randomised control trial in the US studied the consumer decision-making effect of green low-climate impact labels on menu items compared to red high-climate impact labels on red meat items. Results showed that both labels encouraged the purchase of sustainable menu items more than the control group (Wolfson et al., 2022). Eco-labelling can be seen in practice with Just Salad, the first restaurant chain that utilises 'carbon labels' on their menus to indicate the estimated carbon footprint of each meal (Just Salad, 2022). Grocery stores can also increase consumption of plant-based products through information. Lucky, a retail grocery store chain in Northern California, launched an in-store campaign to inform shoppers of the numerous plant-based options in the grocery store (PBFA, 2018).

Not only is investing in plant-based meat alternatives commonplace, it is also happening among traditional meat and dairy producers. For example, Tyson Foods started its own plant-based chicken, sausage and burgers brand called Raised & Rooted, which can be purchased in select grocery stores throughout the country (Raised & Rooted, 2022). In response to consumer demand for health-conscious and sustainably produced proteins, another of the largest US agri-food companies, Cargill, created its own plant-based brand of alternative meats

called Crave House, producing burgers, grounds, crumbles, sausages and meatballs (Cargill, 2021). While this is a step toward more alternative protein production, the involvement of such large corporations could lead to significant harm across the food system, including potential negative impacts on small-scale farmers and producers, reduced competition, and limited consumer choices (Howard, 2021). However, assuming anti-trust laws are enforced and the plant-based movement continues to grow, meat producers of various sizes can remain competitive in the alternative protein market. Government investment in research and development, as well as in procurement at government facilities, as mentioned in the previous section, can help facilitate this process. Forward thinking meat producers also have a role to play by investing in technologies to reduce meat's current environmental footprint, particularly for beef (Hyland et al., 2017; EPA, 2018; Trewern et al., 2022).

Incentivising consumption of meat alternatives would further increase activity in this area. For example, Impossible Foods announced a 20% price drop on their products in grocery stores across the nation (Woodside, 2021). The company's goal is to reach parity with conventional beef products and eventually to become more affordable than conventional beef. While the prices of alternative protein foods are still higher than traditional meat products, this price cut paves the way for greater access to alternative meat options.

The non-profit and philanthropic sectors also have a role to play in this movement (Table 4). Information campaigns from the non-profit sector about the environmental and health benefits of alternatives to meat can help promote public demand. For example, an advocacy coalition associated with the UN Sustainable Development Goal to end hunger, launched the 'Beans is How' campaign to inform consumers about various nutritious, affordable, and climate friendly beans (Beans is How, 2022). To increase the availability of alternative meats and dairy foods, several philanthropists and business executives invested in the Nature's Fynd startup, which plans to use fungi as the primary ingredient in their products (Woods, 2021). Researchers also have a role to play in these activities; a field experiment in the Netherlands tested whether menus with plant-based products as the default option increased purchase of those items compared to traditional meat options, which were also available on the menus. Making the alternative protein meals the default option successfully nudged more consumers to choose that option (Taufik et al., 2022).

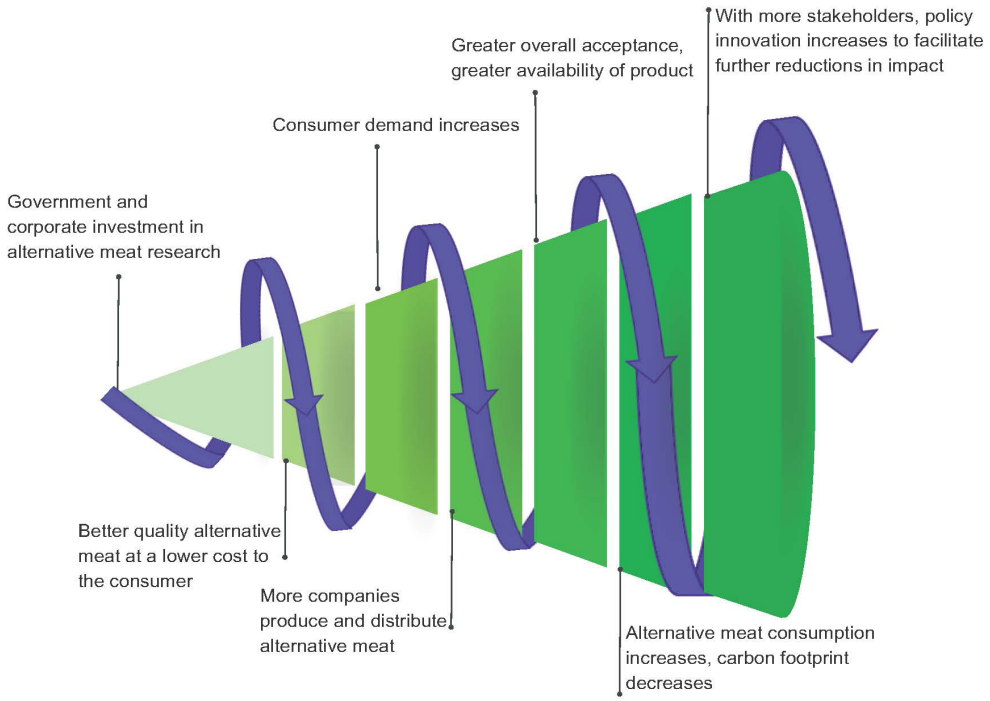
Table 4. Examples of actions for non-profit and philanthropic organisations

Type of intervention	Funder	Advocate
Inform	Bill & Melinda Gates Foundation committed $250,000 to the Good Food Institute (Bill & Melinda Gates Foundation, 2018)	Beans is How campaign (Beans is How, 2022) World Resources Institute's initiative of Cool Food Meal labels for restaurants to indicate low-carbon footprint meal options (WRI, 2023) Foundation Earth works with brands to put front-of-pack sustainability labels on products (Foundation Earth, n.d.) Meatless Monday Messaging (Rayala, 2022)
Invest	Jeff Bezos, Bill Gates, Al Gore and others invest $158 million in Nature's Fynd, an alternative meat and dairy start up using fungus as primary ingredient (Woods, 2021)	One Meal A Day's North Carolina Pilot Program for increased plant-based school lunch options (OMD, 2023)
Incentivise	INGKA Foundation provides plant-based dishes at all IKEA restaurants and bistros and Swedish Food Markets (Ingka Holding, 2020)	Greener By Default empowers institutions to serve plant-based food as default option (GBD, n.d.) Netherlands field experiment demonstrated that plant-based default menu items nudged more consumers to choose those options (Taufik, 2022)

Spiral Up, Spiral Down: A Synergising, Positive Feedback Loop Approach

Several authors have described a cycle of inertia in which governments are afraid to act and the public, not seeing government action, underestimates the extent of the problem. This lack of public awareness, in turn, facilitates government inaction, since there is no pressure to intervene (Bonnet et al., 2020, Wellesley et al., 2015). This contrasts with what could happen when the actions proposed above create positive feedback loops or when they create synergies with other actions. Kelsey (2021) has described a 'green spiral' to explain the interaction between government policy and industry investment to reduce chlorofluorocarbons (CFCs) for protecting the ozone layer. In this example, the first international policies by governments to restrict CFCs led to major investments by some industries, which then became committed and lobbied governments for stronger regulations, which in turn led to more industry investment. This is the essence of a positive feedback loop, where government policies influence industry actions, which then reinforce government policies. This process has also been applied and expanded to describe increases in climate-saving technologies in the energy and automotive sectors (Meyer, 2021), as well as in the alternative meats sector (Smith, 2021; Dutkiewicz, 2021).

Figure 1. An alternative meats spiral offers an example of how positive feedback loops accelerate the acceptance of alternative meats among the general public and industry stakeholders, which can lead to additional policy actions. These concepts were inspired by Kelsey (2021), Meyer (2021), and Smith (2021).



In Figure 1, we outline the characteristics of a positive feedback loop as applied to meat alternatives. We include consumers in the feedback loop, since they will demand more of these foods as they get tastier and cheaper, which prompts expanded industry investment and innovation, leading to even tastier and cheaper products, which eventually can build coalitions for enhanced government actions, including enforcement. As alternative meats improve in taste and cost, producers of traditional meats may reduce their environmental impact, to better compete in this respect. The net result is likely to be increased consumption of alternative meats, decreased consumption of traditional meats, and reduced footprints for those traditional meats that are consumed. As this process unfolds, more stakeholders in the alternative meats sector will mean increased

political power. This may eventually lead to a realignment of US farm subsidy policy, which has historically favoured animal agriculture and its supporting industries, rather than a plants-for-humans approach (Sewell, 2020). This is just one example of an alternative meat spiral. There could also be a plant protein spiral that is not modelled on traditional meats, but rather emphasises the culinary and cultural aspects of legumes, nuts and seeds. Investing in tasty and economical recipes using these foods could increase their availability in restaurants, which could nudge consumers to choose them more frequently, furthering the spiral as with meat alternatives. Whether initiated by government, private industry, or the non-profit sector, these spirals are not guaranteed and depend on actions by more than one sector that reinforce one another. In the CFC example above, government policies started the spiral and were followed by industry investments. With alternative meats, several companies have already invested in research and development, but their uptake has stalled, likely due to price and quality issues for consumers. Government support, similar to that proposed in the PLANT Act, could address this and reinvigorate the spiral.

Conclusions

In summary, the approach we outline incorporates a diversity of actions undertaken by all of society, including government incentives, and focuses on building synergies and positive feedback loops to reduce meat consumption and production. The focus on incentives is due to the political difficulty of enacting disincentives or restrictive policies in the US, given the political strength of the agricultural sector (Vallone and Lambin, 2023). This is not a universal barrier, and other countries – including Spain, Switzerland, New Zealand, Germany and the Netherlands – have formally proposed and/or introduced a tax, levy, or tariff on meat in recent years, all designed to reduce individual consumption of meat (Remmers, 2021). However, such taxes may require considerably high levels to be effective at achieving climate targets (Latka et al., 2021), indicating a trade-off between effectiveness and feasibility.

Our exclusion of restrictive policies does not mean that they are never warranted; rather, they were left out of the discussion due to our focus on the current US national political context. Supplementary Table 2 (at the end of this paper) provides example actions that may be appropriate in other situations, which is important given the context-specific requirements of successful policies (Rust et al., 2020). Even within the US, some policies that are not currently possible at federal level, like taxes on sugar-sweetened beverages, could be successfully implemented at state or local level (Falbe, 2020; Espinosa-Marròn et al., 2022).

We have argued for the importance of food industry involvement in this overall approach, and have suggested that government information, investment, and incentivisation schemes could help to encourage its adoption by industry – and consequently by consumers. However, the food industry's prime concern is with profitability, and there is a growing body of literature that describes how corporations have used political influence to promote their goals, often at odds with health or sustainability (Mialon et al., 2015; Lazarus et al., 2021; Rose et al., 2021; Vallone and Lambin, 2023). Thus, government enforcement will become an important tool to ensure that industry follows through on actions that were previously incentivised. This process was seen in the CFC example described above, as well as in the US transportation sector, where incentives to purchase electric cars (The White House, 2023) were later followed by new rules for emissions targets (Dawson, 2023) and fuel economy standards (Domonoske, 2023). This carrot-before-the-stick approach can work because some industry actors are more likely to adopt a clean technology if there are government incentives to do so, and then, once invested in the technology, are less resistant to new regulations because their new technology already makes them compliant. In other words, becoming more involved in a technology and moving further along the spiral enables such enforcement to become politically feasible (see Figure 1).

Our commentary has focused solely on reducing meat's impact through alternative production and consumption strategies. Clearly there are other important avenues for making our food systems more sustainable, most notably the reduction of food waste (Clark et al., 2020), which was beyond the scope of the present article.

Another important consideration that has not been addressed here is the equilibrium between supply and demand. Reduction in meat consumption by American consumers will not lessen environmental impacts if the commodity is still produced in the same volume but exported instead. The reduced impact on production due to the potential for meat exports has been described by several European investigators (Lehtonen and Irz, 2013; Tukker et al., 2011) and highlights the importance of global solutions to this problem. Winders and Ransom (2019) also emphasise that the global meat industry operates as an interconnected system, where changes in one region can have ripple effects worldwide. This interconnectedness demonstrates the necessity for international cooperation and policymaking to address the environmental impacts of meat production effectively, ensuring that efforts are not limited to the US but are part of a global strategy. Lastly, this review has not addressed the food access inequities that are a significant part of the US food system (Ayazi & Elsheikh, 2015). We recognise that access to sustainable diet choices can be due to factors beyond an individual's control (Giancatarino & Noor, 2014), and that the feasibility of adopting this approach may vary.

A key aspect of our approach is its all-of-society perspective, which resonates with the writing of Rust and colleagues (2020), who argue for actions across the whole supply chain. The positive feedback loop embodied by a spiral is also essential to our approach. This is similar to the concept of positive tipping points to drive sustainability, as advanced by Lenton and colleagues (2021), in that small changes can trigger self-reinforcing feedback to accelerate change. All of these approaches share a common optimism that changes implemented by actors across the food system can create the needed momentum towards achieving sustainability goals.

References

Achuthan, V. K. (2022). Students demand 100% plant-based universities. Surge. https://www.surgeactivism.org/articles/students-demand-100-plant-based-universities [Accessed February 10, 2023].

Agyemang P, Kwofie EM and Baum JI. (2022). Transitioning to sustainable healthy diets: A model-based and conceptual system thinking approach to optimized sustainable diet concepts in the United States. Frontiers in Nutrition, 9(874721). https://doi.org/10.3389/fnut.2022.874721

Aleph Farms. (2021). Meat for Earth. https://www.aleph-farms.com/our-steak-1 [Accessed March 20, 2023].

Anderson, B and Gross, J. (2021). The New Menu at Eleven Madison Park Will Be Meatless. The New York Times. https://www.nytimes.com/2021/05/03/dining/eleven-madison-park-vegan-menu.html [Accessed April 19, 2023].

Arkansas Department of Agriculture. (2023). Arkansas Grown Grant for NWA Farmers. Arkansas Grown. https://arkansasgrown.org/grant-pilot-program/ [Accessed February 10, 2023].

Atkin, Emily. 2019. The potency of Republicans' hamburger lie. The New Republic. https://newrepublic.com/article/153187/potency-republicans-hamburger-lie [Accessed March 5, 2023].

Ayazi, H., & Elsheikh, E. (2015). The US Farm Bill: Corporate Power and Structural Racialization in the United States Food System. Haas Institute. https://belonging.berkeley.edu/farm-bill-report-corporate-power-and-structural-racialization-us-food-system [Accessed April 21, 2023].

Bazoche, P., Guinet, N., Poret, S., & Teyssier, S. (2023). Does the provision of information increase the substitution of animal proteins with plant-based proteins? An experimental investigation into consumer choices. Food Policy, 116, 102426. https://doi.org/10.1016/j.foodpol.2023.102426

Bazzi, S., Fiszbein, M., & Gebresilasse, M. (2021). Rugged individualism and collective (in)action during the COVID-19 pandemic. Journal of Public Economics, 195. https://doi.org/10.3386/w27776

Beans is How. (2022). Why Beans? https://beansishow.org/why-beans/ [Accessed February 5, 2023].

Bernstein, J., & Dutkiewicz, J. (2021). A Public Health Ethics Case for Mitigating Zoonotic Disease Risk in Food Production. Food ethics, 6(2), 9. https://doi.org/10.1007/s41055-021-00089-6

Beyond Meat. (2020). Empowering the Next Generation. https://www.beyondmeat.com/en-US/whats-new/empowering-the-next-generation [Accessed March 2, 2023].

Beyond Meat. (2023). Our Products. https://www.beyondmeat.com/en-US/products/[Accessed March 2, 2023].

Bill & Melinda Gates Foundation. (2018). The Good Food Institute. https://www.gatesfoundation.org/about/committed-grants/2018/10/opp1196044 [Accessed January 20, 2023].

Bonnet, C., Bouamra-Mechemache, Z., Réquillart, V., & Treich, N. (2020). Viewpoint: Regulating meat consumption to improve health, the environment and animal welfare. Food Policy, 97 (101847). https://doi.org/10.1016/j.foodpol.2020.101847.

Breewood, H., & Garnett, T. (2023). Meat, metrics and mindsets: Exploring debates on the role of livestock and alternatives in diets and farming. TABLE Explainer. TABLE, University of Oxford, Swedish University of Agricultural Sciences and Wageningen University and Research. https://doi.org/10.56661.2caf9b92

Brink E., van Rossum, C., Postma-Smeets, A., Stafleu, A., Wolvers, D., van Dooren, C., et al. (2019). Development of healthy and sustainable food-based dietary guidelines for the Netherlands. Public Health Nutrition, 22(13), 2419–35. https://doi.org/10.1017/S1368980019001435

Brower, J. (2022). Reviewing the Tariff-Rate Quotas for U.S. Beef Imports. U.S. Department of Agriculture Foreign Agriculture Service. https://www.fas.usda.gov/sites/default/files/2022-12/Beef-Quota-IATR-Final_1.pdf

Buxton, A. (2023). 'There is No Alternative': Lidl Announces Plans to Reduce Meat in Stores. Plant Based News.

https://plantbasednews.org/news/economics/lidl-reduces-meat-products/ [Accessed February 25, 2023].

California Department of Education [CDE]. (2018). Powering up with plant-based programs. Food Service Staff Education and Training. https://www.cde.ca.gov/ls/nu/ed/course894.asp [Accessed January 10, 2023].

Cargill, Incorporated. (2021). Increasing demand for alternative proteins leads to Cargill's New Crave HouseTM Brand. Cargill Protein Distributors. https://distributors.cargill.com/cargills-alternative-protein-solution/ [Accessed July 2, 2024]

Clark, M. A., Domingo, N. G. G., Colgan, K., Thakrar, S. K., Tilman, D., Lynch, J., Azevedo, I. L., & Hill, J. D. (2020). Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets. Science, 370(6517), 705–708. https://doi.org/10.1126/science.aba7357

Budget Act of 2022, CA AB154, 6440-001-0001 (2021). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml [Accessed Mach 6, 2023].

California State Senate. (2018). Governor Brown signs senator Skinner's SB 1138 to offer plant-based meal options in hospitals, healthcare facilities and Prisons. Senator Nancy Skinner. https://sd09.senate.ca.gov/news/20180918-governor-brown-signs-senator-skinner%E2%80%99s-sb-1138-offer-plant-based-meal-options [Accessed January 10, 2023].

Capper, J. L. (2011). The environmental impact of beef production in the United States: 1977 compared with 2007. Journal of Animal Science, 89(12), 4249–4261, https://doi.org/10.2527/jas.2010-3784

Capritto, A. (2019). Impossible Burger vs. Beyond Meat Burger: Taste, ingredients and availability, compared. CNET. https://www.cnet.com/health/nutrition/beyond-meat-vs-impossible-burger-whats-the-difference/ [Accessed March 15, 2023].

City of New York. (2022). Mayor Adams, American College of Lifestyle Medicine Announce $44 Million to Offer Lifestyle Medicine Foundational Training to Every NYC Health Care Practitioner. https://www.nyc.gov/office-of-the-mayor/news/879-22/mayor-adams-american-college-lifestyle-medicine-44-million-offer-lifestyle?s=09#/0 [Accessed February 10, 2023].

Colby College. (n.d.). Academics: Sustainable Dining. https://www.colby.edu/academics/departments-and-programs/environmental-studies/about/campus-sustainability/sustainable-dining/ [Accessed February 27, 2023].

Cook, R. (2023). Rankings of Countries That Produce The Most Beef (USDA). Beef2Live. https://beef2live.com/story-world-beef-production-ranking-countries-0-106885 [Accessed February 10, 2023].

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., & Leip, A. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food, 2(3), 198–209. https://doi.org/10.1038/s43016-021-00225-9

Cunningham, B. (2022). How food became a weapon in America's culture war. Food and Environment Reporting Network. https://thefern.org/2022/12/how-food-became-a-weapon-in-americas-culture-war/ [Accessed April 21, 2023].

Dawson M. (2023). EPA's new standards will accelerate transition to electric vehicles. Environmental and Energy Study Institute. https://www.eesi.org/articles/view/epas-new-standards-will-accelerate-transition-to-electric-vehicles# [Accessed August 1, 2023).

DC Law Library. (2019). Healthy Students Amendment Act of 2018. D.C. Law 22-240. https://code.dccouncil.gov/us/dc/council/laws/22-240 [Accessed March 2, 2023].

Domonoske C. (2023). Biden administration proposed new fuel economy standards, with higher for trucks. NPR.

https://www.npr.org/2023/07/28/1190799503/new-fuel-economy-standards-cars-trucks# [Accessed August 1, 2023].

Dumas, P., Wirsenius, S., Searchinger, T., Andrieu, N., & Vogt-Schilb, A. (2022). Options to achieve net-zero emissions from agriculture and land use changes in Latin America and the Caribbean. Inter-American Development Bank. https://doi.org/10.18235/0004427

Dutkiewicz, J. (2021). How Do You Convince People to Eat Less Meat? The New Republic. https://newrepublic.com/article/163079/convince-people-eat-less-meat [Accessed July 21, 2023].

Environmental Protection Agency (EPA). (2018). Market Opportunities for Biogas Recovery Systems at U.S. Livestock Facilities. United States Environmental Protection Agency. https://www.epa.gov/sites/default/files/2018-06/documents/epa430r18006agstarmarketreport2018.pdf

Espinosa-Marrón A, Adams K, Sinno L, Cantu-Aldana A, Tamez M, Marrero A, Bhupathiraju SN and Mattei J (2022) Environmental Impact of Animal-Based Food Production and the Feasibility of a Shift Toward Sustainable Plant-Based Diets in the United States. Frontiers In Sustainability, 3:841106. doi: 10.3389/frsus.2022.841106

Food and Agriculture Organization of the United Nations [FAO]. (2011). The State of the World's Land and Water Resources for Food and Agriculture (SOLAW)—Managing Systems at Risk. Rome, Italy: Food and Agriculture Organization of the United Nations and Earthscan.

Food and Agriculture Organization of the United Nation [FAO]. (2023). Consumers can make a difference towards more sustainable agri-food ystems. The Right to Food. https://www.fao.org/right-to-food/resources/resources-detail/en/c/1381121/#:~:text=Consumers%20can%20influence%20the%20sustainable,and%20preservation%20of%20our%20natural

FoodPrint. (2023). Eating Meat Sustainably. GRACE Communications Foundation. https://foodprint.org/eating-sustainably/eating-meat-sustainably/ [Accessed April 5, 2023].

Falbe, J., Grummon, A. H., Rojas, N., Ryan-Ibarra, S., Silver, L. D., & Madsen, K. A. (2020). Implementation of the First US Sugar-Sweetened Beverage Tax in Berkeley, CA, 2015-2019. American journal of public health, 110(9), 1429–1437. https://doi.org/10.2105/AJPH.2020.305795

Foundation Earth. (n.d.) About Us. https://www.foundation-earth.org/about-us/ [Accessed February 20, 2023].

Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G. (2013). Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations, Rome.

Giancatarino, A., & Noor, S. (2021). Building the case for racial equity in the food system. Race Forward https://www.raceforward.org/research/report/building-the-case-for-racial-equity-in-the-food-system [Accessed April 21, 2023].

Good Food Purchasing Program. (n.d.) Pittsburgh. https://goodfoodcities.org/pittsburgh-uses-school-lunches-to-take-on-environmental-and-labor-issues/ [Accessed March 5, 2023].

Government of Canada. (2019-a). Protein Supercluster starts off with first project to boost crop value. https://www.canada.ca/en/innovation-science-economic-development/news/2019/06/protein-supercluster-starts-off-with-first-project-to-boost-crop-value.html [Accessed February 15, 2023].

Government of Canada. (2019-b). Canada's Dietary Guidelines. Health Canada. https://food-guide.canada.ca/en/guidelines/ [Accessed February 15, 2023].

Greener by Default [GBD]. (n.d.). Empowering institutions to serve sustainable, inclusive food — by default. https://www.greenerbydefault.com/ [Accessed February 25, 2023].

Grummon A.H., Lee, C..JY., Robinson, T.N., Rimm, E.G., & Rose, D. (2023). Simple dietary substitutions can reduce carbon footprints and improve dietary quality across diverse segments of the US population. Nature Food. https://doi.org/10.1038/s43016-023-00864-0.

Guthman, J., & Biltekoff, C. (2020). Magical disruption? Alternative protein and the promise of de-materialization. Environment and Planning E: Nature and Space. doi:10.1177/2514848620963125

Hedenus F, Wirsenius S, Johansson DJA. (2014). The importance of reduced meat and dairy consumption for meeting

stringent climate change targets. Clim Change. (124) 79-91.

Heller, M., Willits-Smith, A., Meyer, R., Keoleian, G., & Rose, D. (2018). Greenhouse gas emissions and energy use associated with production of individual self-selected US diets. Environmental Research Letters. 13. 044004. 10.1088/1748-9326/aab0ac

Howard, P. H. (2021). Concentration and power in the food system: Who controls what we eat? Bloomsbury Academic.

Hyland, J. J., Henchion, M., McCarthy, M., & McCarthy, S. N. (2017). The role of meat in strategies to achieve a sustainable diet lower in greenhouse gas emissions: A Review. Meat Science, 132, 189–195. https://doi.org/10.1016/j.meatsci.2017.04.014

Ingka Holding. (2020). Our plant-based movement. https://www.ingka.com/projects/our-plant-based-movement/ [Accessed February 25, 2023].

IOM (Institute of Medicine) and NRC (National Research Council). (2015) "Overview of the U.S. Food System," in A Framework for Assessing Effects of the Food System. Washington, DC: The National Academies Press, 31-45

Impossible Foods, Inc. (2023). Our Products. https://impossiblefoods.com/products [Accessed March 2, 2023].

International Panel on Climate Change [IPCC]. (2019). Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, et al, (eds.)].

Ivanovich, C. C., Sun, T., Gordon, D. R., & Ocko, I. B. (2023). Future warming from global food consumption. Nature Clim Change, 13, 297–302. https://doi.org/10.1038/s41558-023-01605-8

Just Salad. (2022). Make Carbon Count. https://justsalad.com/carbonlabel [Accessed March 15, 2023].

Kelsey, N. (2021). International ozone negotiations and the Green Spiral. Global Environmental Politics, 1–24. https://doi.org/10.1162/glep_a_00631

The Kroger Co. (2020). Kroger's Simple Truth Brand Expands Plant Based Collection with Launch of Emerge Chick'n and 50+ New Items. https://ir.kroger.com/CorporateProfile/press-releases/press-release/2020/Krogers-Simple-Truth-Brand-Expands-Plant-Based-Collection-with-Launch-of-Emerge-Chickn-and-50-New-Items/default.aspx [Accessed March 2, 2023].

Latka, C., Heckelei, T., Batka, M., Boere, E., Chang, C-Y., Cui, D., Geleijnse, M., Havlík, P., Kuijsten, A., Kuiper, M., Leip, A., van 't Veer, P., Witzke, H-P., & Ziegler, F. (2018). The potential role of producer and consumer food policies in the EU to sustainable food and nutrition security. SUSFANS. https://edepot.wur.nl/464089

Latka, C., Kuiper, M., Frank, S., Heckelei, T., Havlík, P., Witzke, H.-P., Leip, A., Cui, H. D., Kuijsten, A., Geleijnse, J. M., & van Dijk, M. (2021). Paying the price for environmentally sustainable and healthy EU DIETS. Global Food Security, 28(100437). https://doi.org/10.1016/j.gfs.2020.100437

Lazarus, O., McDermid, S. & Jacquet, J. (2021). The Climate Responsibilities of Industrial Meat and Dairy Producers. Climatic Change 165, 30 (2021). https://doi.org/10.1007/s10584-021-03047-7

Lehtonen, H., Irz, X. (2013). Impacts of reducing red meat consumption on agricultural production in Finland. Agric. Food Sci. 22, 356–370.

Lenton, T. M., Benson, S., Smith, T., Ewer, T., Lanel, V., Petykowski, E., Powell, T. W., Abrams, J. F., Blomsma, F., & Sharpe, S. (2022). Operationalising positive tipping points towards Global Sustainability. Global Sustainability, 5, 1–16. https://doi.org/10.1017/sus.2021.30

Mattox, C. (2024). It's alive: The legislative response to cell-cultured synthetic meat. Energy & Environment. https://www.multistate.us/insider/2024/5/8/its-alive-the-legislative-response-to-cell-cultured-synthetic-meat [Accessed July 2, 2024].

McGovern, J. (2023). McGovern Introduces New Bill to Support American Farmers and Rural Communities through Plant-Based Food Production. Press Releasehttps://mcgovern.house.gov/news/documentsingle.aspx?DocumentID=400022 [Accessed August 9, 2023]

Meyer, R. (2021). How the U.S. Made Progress on Climate Change Without Ever Passing A Bill. The Atlantic. https://www.theatlantic.com/science/archive/2021/06/climate-change-green-vortex-america/619228/ [Accessed January 10, 2023].

Mialon, M., Swinburn, B. & Sacks, G. (2015). A proposed approach to systematically identify and monitor the corporate political activity of the food industry with respect to public health using publicly available information. Obes Rev, 16, 519-30.

National Defense Authorization Act for Fiscal Year 2023, H.R. 7900, 117th Cong. (2022). https://www.congress.gov/bill/117th-congress/house-bill/7900/text [Accessed February 15, 2023].

New York City Department of Education [NYC DOE]. (2023). Plant Powered Meals. School Meals. https://www.schools.nyc.gov/school-life/food/school-meals/plant-powered [Accessed March 2, 2023].

Nuffield Council on Bioethics. (2007). Policy Process and Practice. Public Health: Ethical Issues. https://www.nuffield-bioethics.org/publications/public-health/guide-to-the-report/policy-process-and-practice [Accessed October 24, 2022].

Nutrition Incentive Hub. (n.d.). GusNIP Funding. https://www.nutritionincentivehub.org/funding/gusnip-funding [Accessed October 22, 2022].

One Meal a Day [OMD]. (2020). The OMD Movement. https://omdfortheplanet.com/what-is-omd/the-movement/ [Accessed March 1, 2023].

PayVegan Hong Kong Limited. (2021). Pay-A-Vegan: Your One Solution Advertising & Loyalty Program. https://veryfatpiggy.wixsite.com/website-3 [Accessed February 27, 2023].

PLANT (Peas, Legumes, And Nuts Today) Act, 118th Cong., H.R.5023 (2023).

https://www.congress.gov/bill/118th-congress/house-bill/5023/all-actions?overview=closed#tabs [Accessed July 2, 2024].

Plant Based Foods Association. (2018). PBFA & Lucky "Fall in Love with Plant Based" Retail Campaign. https://www.plantbasedfoods.org/pbfa-lucky-fall-in-love-with-plant-based-retail-campaign/ [Accessed February 20, 2023].

Poore J, Nemecek T. (2018). Reducing food's environmental impacts through producers and consumers. Science. 360: 987–92.

PRS Legislative Research. (2021). The Karnataka Prevention of Slaughter and Preservation of Cattle Act, 2020. https://prsindia.org/acts/states [Accessed October 24, 2022].

Rayala, H.-T., Rebolledo, N., Hall, M. G., & Taillie, L. S. (2022). Perceived message effectiveness of the meatless Monday campaign: An experiment with US adults. American Journal of Public Health, 112(5), 724–727. https://doi.org/10.2105/ajph.2022.306766

Raised & Rooted. (2022). Products. https://www.raisedandrooted.com/products/ [Accessed February 10, 2023].

Reinicke, C. (2019). These are Beyond Meat's 16 highest-profile partnerships in the food industry. Business Insider. https://markets.businessinsider.com/news/stocks/10-most-high-profile-beyond-meat-partnerships-in-food-industry-2019-7-1028381863 [Accessed February 27, 2023].

Remmers, J. (2021). Increasing number of countries start taxing meat and dairy. True Animal Protein Price Coalition. https://www.tappcoalition.eu/nieuws/16831/increasing-number-of-countries-start-taxing-meat-and-dairy- [Accessed October 24, 2022].

Resnik, D. (2010). Trans fat bans and human freedom. The American Journal of Bioethics, 10(3), 27–32. https://doi.

org/10.1080/15265160903585636

Rogers, K. (2020). Want to eat less meat? Take a page from these cultures that already do. Cable News Network Travel. https://www.cnn.com/travel/article/vegetarian-diet-beginners-coronavirus-wellness/index.html [Accessed April 5, 2023].

Rose, D., Heller, M. C., & Roberto, C. A. (2019). Position of the Society for Nutrition Education and Behavior: The Importance of Including Environmental Sustainability in Dietary Guidance. Journal of nutrition education and behavior, 51(1), 3–15.e1. https://doi.org/10.1016/j.jneb.2018.07.006

Rose, D., Vance, C. & Angel Lopez, M. (2021). Livestock Industry Practices that Impact Sustainable Diet Policies in the United States. International Journal of Sociology of Agriculture & Food, 27, 1, 35-53. https://doi.org/10.48416/ijsaf.v27i1.87

Rose, D., Willits-Smith, A. M., & Heller, M. C. (2022). Single-item substitutions can substantially reduce the carbon and water scarcity footprints of US diets. The American journal of clinical nutrition, 115(2), 378–387. https://doi.org/10.1093/ajcn/nqab338

Rust, N. A., Ridding, L., Ward, C., Clark, B., Kehoe, L., Dora, M., Whittingham, M. J., McGowan, P., Chaudhary, A., Reynolds, C. J., Trivedy, C., & West, N. (2020). How to transition to reduced-meat diets that benefit people and the planet. Science of The Total Environment, 718(137208). https://doi.org/10.1016/j.scitotenv.2020.137208

Sabarwal, H. (2022). Animal Slaughter, sale of meat banned in Bengaluru on Gandhi Jayanti. Hindustan Times. https://www.hindustantimes.com/cities/bengaluru-news/animal-slaughter-sale-of-meat-banned-in-bengaluru-on-gandhi-jayanti-101664535277353.html [Accessed October 24, 2022].

Sewell, C. (2020). Removing the Meat Subsidy: Our Cognitive Dissonance Around Animal Agriculture. Columbia Journal of International Affairs. https://jia.sipa.columbia.edu/removing-meat-subsidy-our-cognitive-dissonance-around-animal-agriculture#7 [Accessed March 4, 2023].

Sheldon, M. (2021). Berlin University Cafeterias remove meat from menus to reduce climate change. NYC Food Policy Center. https://www.nycfoodpolicy.org/food-policy-snapshot-berlin-university-cafeterias-remove-meat/ [Accessed October 24, 2022].

Smith, A. (2021). The Coming "Meat Vortex". The Breakthrough Institute. https://thebreakthrough.org/journal/no-15-winter-2022/meat-vortex-alternative-protein [Accessed October 24, 2022].

Smith, A., Shah, S. & Blaustein-Rejto, D. (2021). The Case for Public Investment in Alternative Proteins. The Breakthrough Institute. https://s3.us-east-2.amazonaws.com/uploads.thebreakthrough.org/Alternative-Protein-Report_v6.pdf [[Accessed November 20, 2022].

Specht, J. (2019). Red Meat Republic: A Hoof-to-Table History of How Beef Changed America. Princeton University Press. https://doi.org/10.2307/j.ctvc77mqs

Tamarkin, D., & Hoffman, M. (2021). The planet on the plate: Why Epicurious left beef behind. Epicurious. https://www.epicurious.com/expert-advice/why-epicurious-left-beef-behind-article [Accessed March 10, 2023].

Tanner, J. (2021). Finland's capital to ditch meat for climate, with exceptions. AP News. https://apnews.com/article/business-lifestyle-europe-environment-and-nature-finland-9391e023081a42091602be245bbd5d02 [Accessed March 23, 2023].

Taufik, D., Bouwman, E., Reinders, M., Dagevos, H. (2022). A reversal of defaults: Implementing a menu-based default nudge to promote out-of-home consumer adoption of plant-based meat alternatives. Appetite, 175. https://doi.org/10.1016/j.appet.2022.106049

Tekiner, İ. H. (2021). Turkish Cuisine: A Planet- and Vegan-Friendly Food, Culture, and Folklore. International Journal of Information Systems and Social Change (IJISSC), 12(1), 23-31. http://doi.org/10.4018/IJISSC.2021010103

The Good Food Institute. (2021). World's First Industry-based LCA & TEA Show That Cultivated Meat Can Be Environmentally Beneficial and Economically Viable.

Trewern, J., Chenoweth, J., & Christie, I. (2022). "Does it change the nature of food and capitalism?" Exploring expert perspectives on public policies for a transition to 'less and better' meat and dairy. Environmental Science & Policy, 128, 110-120. https://doi.org/10.1016/j.envsci.2021.11.018

Tukker, A., Goldbohm, R.A., de Koning, A., Verheijden, M., Kleijn, R., Wolf, O., Perez-Dominguez, I., Rueda-Cantuche, J.M., 2011b. Environmental impacts of changes to healthier diets in Europe. Ecol. Econ. 70(10), 1776–1788.

Tyson Foods. (2022). Offers. https://www.tysonfoodservice.com/offers [Accessed February 27, 2023].

The Monday Campaigns. (2003). About Meatless Monday. https://www.mondaycampaigns.org/meatless-monday/about [Accessed March 5, 2023].

Upside Foods. (2023). Food. https://www.upsidefoods.com/food [Accessed March 20, 2023].

United Nations Educational, Scientific, and Cultural Organization. (2020). United Nations World Water Development Report 2020: Water and Climate Change. Paris (France): UNESCO.

United States Department of Agriculture [USDA] and U.S. Department of Health and Human Services [DHHS]. (2024). Dietary Guidelines for Americans 2020–2025, 9th ed. http://www.dietaryguidelines.gov [Accessed on July 1 2024]

United States Department of Agriculture [USDA]. (2024). World Agricultural Supply and Demand Estimates. WASDE Report. https://www.usda.gov/oce/commodity/wasde/wasde0624.pdf [Accessed June 24, 2024].

United States Department of Agriculture Economic Research Service [USDA ERS]. (2024). Livestock, Dairy, and Poultry Outlook: February 2024. https://www.ers.usda.gov/webdocs/outlooks/108574/ldp-m-356.pdf?v=8866.1#:~:text=Looking%20back%20at%202023%2C%20the,17%20percent%20year%20over%20year. [Accessed July 17, 2024].

Vallone & Lambin. (2023). Public policies and vested interests preserve the animal farming status quo at the expense of animal product analogs, One Earth (6), 1-14. https://doi.org/10.1016/j.oneear.2023.07.013

Véliz, C., Maslen, H., Essman, M., Taillie, L. S., & Savulescu, J. (2019). Sugar, taxes, & choice. Hastings Center Report, 49(6), 22–31. https://doi.org/10.1002/hast.1067

Wellesley, L., Happer, C., & Froggatt, A. (2015). Changing Climate, Changing Diets Pathways to Lower Meat Consumption. Chatham House Report. https://www.chathamhouse.org/sites/default/files/publications/research/CHHJ3820 Diet and climate change 18.11.15_WEB_NEW.pdf

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L. J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J. A., De Vries, W., Majele Sibanda, L., … Murray, C. J. (2019). Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet, 393(10170), 447–492. https://doi.org/10.1016/s0140-6736(18)31788-4

Willits-Smith, A., Aranda, R., Heller, M. C., & Rose, D. (2020). Addressing the carbon footprint, healthfulness, and costs of self-selected diets in the USA: a population-based cross-sectional study. The Lancet: Planetary health, 4(3), e98–e106. https://doi.org/10.1016/S2542-5196(20)30055-3

Winders, W., & Ransom, E. (2019). Global Meat: Social and environmental consequences of the expanding Meat Industry. The MIT Press.

Woods, B. (2021, July 6). Bezos, Gates back fake meat and dairy made from fungus as next big alt-protein. CNBC LLC. https://www.cnbc.com/2021/07/03/bezos-gates-back-fungus-fake-meat-as-next-big-alt-protein-.html [Accessed February 5, 2023].

Woodside, D. (2021). Better Prices for Consumers, Bigger Impact on the Planet: Why We're Dropping Our Prices in Grocery Stores. Impossible Foods. https://impossiblefoods.com/blog/better-prices-bigger-impact [Accessed Jan 20, 2023].

Wolfson, J. A., Musicus, A. A., Leung, C. W., Gearhardt, A. N., & Falbe, J. (2022). Effect of climate change impact menu

labels on fast food ordering choices among us adults. JAMA Network Open, 5(12). https://doi.org/10.1001/jamanetworkopen.2022.48320

World Population Review. (2023). Smoking Rates by State 2023. State Rankings. https://worldpopulationreview.com/state-rankings/smoking-rates-by-state [Accessed March 21, 2023].

World Resources Institute. (2023). Cool Food. https://www.wri.org/initiatives/cool-food-pledge [Accessed March 3, 2023].

Supplementary Table 1. Crosswalk from our menu to previous policy intervention ladders

Type of intervention	Nuffield Intervention Ladder[1]	Balanced Intervention Ladder[2]	SUSFANS Policy Ranking[3]
Inform	Provide information	Provide information Educate for autonomy	Provide information Educate for autonomy Compulsory information on products Ban marketing to children[4]
Invest		Ensure choice is available	Ensure health choices are available
Incentivise	Enable choice Guide choice through defaults Guide choice through incentives	Guide choice through defaults Enable choice Guide choice through incentives	Nudge through defaults Enable choice through programs[5] Guide choice through incentives
Not on the Menu	Do nothing Monitor the situation Guide choice through disincentives Restrict choice Eliminate choice	Do nothing Monitor the situation Guide choice through disincentives Collective self-binding Restrict choice Eliminate choice	Do nothing Guide choices through disincentives Restrict choice through regulation Eliminate choice

Supplementary Table 2. Examples of actions not included in our menus

Type of Intervention	Sector		
	Government	Industry	Non-Profit & Philanthropic
Disincentivise	Removing meat and dairy subsidies (Sewell, 2020) Estimated environmental benefits of a meat tax in the Netherlands (Broeks et al., 2020)		
Restrict Choice	Bengaluru, India restrict holiday meat sales (Sabarwal, 2022)	German supermarket chain Lidl announced plans to decrease meat and animal product offerings in favour of plant-based alternatives (Buxton, 2023)	Epicurious (online magazine) no longer publishing new beef recipes (Tamarkin & Hoffman, 2021)
Eliminate Choice	Helsinki no longer serving meat at seminars, receptions, and other events (Tanner, 2021) Karnakata bans slaughter of cattle (PRS Legislative Research, 2021)	Eleven Madison Park restaurant transitions to fully plant-based menu (Anderson & Gross, 2021)	UK Students demand 100% plant-based universities (Achuthan, 2023)

[1] Nuffield Council on Bioethics. (2007). Policy Process and Practice. Public Health: Ethical Issues. Retrieved October 24, 2022, from https://www.nuffieldbioethics.org/publications/public-health/guide-to-the-report/policy-process-and-practice

[2] Griffiths, P. E., & West, C. (2015). A balanced intervention ladder: Promoting autonomy through Public Health Action. Public Health, 129(8), 1092–1098.

[3] Latka, C., Heckelei, T., Batka, M., Boere, E., Chang, C-Y., Cui, D., Geleijnse, M., Havlík, P., Kuijsten, A., Kuiper, M., Leip, A., van't Veer, P., Witzke, H-P., & Ziegler, F. (2018). The potential role of producer and consumer food policies in the EU to sustainable food and nutrition security. SUSFANS. https://edepot.wur.nl/464089

[4] (..) and other agents with limited decision-making

[5] behavioural change programmes