LEVERAGES FOR ADVANCING CARBON ACCOUNTING IN THE UNITED STATES FOOD SYSTEM:

An analysis of the political and economic leverages through which carbon accounting can serve as an effective tool for reducing net greenhouse gas emissions of the United States' food system

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Executive Summary

The present-day global food system is responsible for 25 to 30% of total greenhouse gas emissions (Boehm et al. 2018; Ritchie, 2019). Food systems are defined as the interconnected processes, systems, and players that deliver and influence food production, preparation, and disposal. Food systems can represent a variety of scales: local, regional, national, international, and global. All scales include actors across the following sectors; producers, processors, distributors, consumers, retailers, and wholesalers (Von Braun, Afsana, Fresco, Hassan, & Torero, 2021).

Life Cycle Analysis (LCA) is the study of a product's life within the linear production model and is a tool for "identifying or comparing the environmental impacts of a product" by assessing their interactions "with the natural environment" (Golisano Institute for Sustainability, 2020, para. 13). The data collected through this process can then be utilized to inform carbon accounting strategies. Carbon accounting, in relation to the food system, is a strategy of budgeting a specified quantity of emissions for a particular product, within a designated time, then only consuming products whose cumulative footprint falls below this quantity ("Carbon Accounting 101," n.d.). Carbon accounting can therefore be utilized as a tool by all sectors of the food system for emissions reduction strategies.

GreenSwapp is a Netherlands-based, for-profit business that is developing an algorithm to quantify carbon equivalent emissions of food products. To achieve this, GreenSwapp connects their database containing thousands of LCAs to their clients' product portfolio, producing carbon footprint estimations for each product, through which the company can employ carbon accounting strategies. The University of Michigan GreenSwapp team was tasked with assessing the feasibility of a federal carbon accounting mandate for food distributors and identifying alternative leverages for intervention within the United States' food system.

To comprehensively understand the feasibility of this mandate, researchers needed to conduct an in-depth analysis of the state of carbon accounting in the US food system, as well as the policy landscape this mandate would be implemented within. This study asks, given that the global food system contributes 25-30% of net carbon emissions, what is a strategy to influence the system components and primary actors to significantly reduce carbon emissions in the US

food system? To approach this question the team, 1) identified the primary sectors of the US food system, 2) conducted a literature review of the current state of carbon accounting including US policy climate in relation to carbon accounting, historical action taken, and influential actors, 3) interviewed three or more stakeholders in all identified food system sectors, and 4) performed a qualitative analysis on interview data.

In this report, we share the current state of carbon accounting in each sector of the food supply chain. In summary, the sustainability initiatives adopted, and internal mechanics of producers depend on the scale of the producer, which comes with distinct challenges. For example, a smaller producer (farm) typically has fewer opportunities, technology, and resources for implementing precision agriculture, regenerative, and/or organic agriculture compared to a larger producer. Alternatively, many processors already calculate their emissions, this is especially true for the vertically integrated companies. It is up to processors to decide what to do with these calculations. While some already have goals set, they require a strong business case for such changes. Processors have influence on their purchasing, packaging, energy, and selling decisions. Sustainability measures within the wholesale sector are primarily implemented through energy reduction and intentional sourcing. However, this only takes place when the company recognizes 1) its profitability and 2) has accurate information about partner emissions. Retailers see their goal as providing what their customers want. Incorporating carbon accounting is difficult at the retail level because it is so far removed from production. This is especially for medium and small-scale retailers and therefore makes them reliant on other sectors for providing data. Large scale retailers are likely to have some amount of vertical integration with other steps in the supply chain. This has the effect of reducing data barriers for assessing their products. Finally, consumers directly interact with carbon accounting only when emissions information is conveyed through labeling. However, because consumers prioritize price and taste, these qualities must overlap with sustainability to have a significant influence.

The policy climate within which a carbon accounting mandate would be implemented including historic and existing policies as well as influential actors, was analyzed at the international, national, state and municipal levels. At the municipal level there is no legal power to require carbon accounting or labeling. However, there is a significant opportunity for local governments to model sustainability as a priority with procurement policies and to encourage businesses and community members to value sustainable choices with voluntary programs and certifications. At the state level, there are 25 states and the District of Columbia that have carbon reduction goals. They are leading the way because there is no established federal goal. Half of the top ten food producing and processing states are in the US Climate Alliance, suggesting that if those five states make headway in reducing emissions, then overall food emissions can also decrease. State laws also have the potential to influence companies nationally, such as California’s Proposition 65 that mandates companies label products with cancer-causing ingredients. Finally, at the federal level, more than 20 different regulatory agencies control the actions and processes of the US food system. Historically, the federal government has largely failed to adopt emissions regulatory standards; in 2022, the Supreme Court ruled that the EPA

could not mandate state emissions caps. However, the recent passing of large climate solutions bills such as the IRA and the Bipartisan Infrastructure Law, are expected to reduce emissions by 40% compared to the 2005 levels by 2030 (US Department of Energy, 2022). One of the programs funded by these laws is the Greenhouse Gas Inventory Assessment Program which will establish carbon accounting standards for food producers. The influence of lobbies, trade organizations, and advocacy organizations with food-based missions, were also determined to have significant influence over the success of the proposed policy, primarily through financing.

A network visualization displaying interview data specifically in relation to questions of sectoral relationships, influence, and power found processors to be the largest leverage for system change.

While countless factors could influence the feasibility of a carbon accounting mandate, five key barriers have been highlighted in this report: barriers for the collection and reliability of associated data (data barriers), lacking regulatory structure and financial resources for policy adoption (resources and regulation), the potential for corporations to misrepresent sustainability-related data for financial gain (greenwashing), prominent political barriers for legislative success (political contention), and the risks of investing time and resources into this policy in relation to others with greater potential for emissions reduction (opportunity cost).

Lastly, this research identified five alternative leverages through which carbon accounting could be utilized as a tool to reduce net US food emissions. These leverages include enhanced investments in the collection and regulation of carbon accounting data, utilizing LCAs for targeted reductions, implementing a state-level carbon accounting mandate, implementing a federal carbon labeling mandate, and utilizing existing programs such as SNAP and the Healthy Eating Index to increase the procurement, affordability, and salience of sustainable food.

The results of this project include a network visualization of the relationships between sectors, an analysis of the policy climate in relation to carbon accounting, and an informed list of alternative leverages for expanding the use and impact of carbon accounting, all in the context of the US food system. Utilizing this information, GreenSwapp, and other organizations promoting the expansion of carbon accounting throughout the US food system, can identify organizational action that optimizes their use of time and resources, while simultaneously maximizing their impact.

Acknowledgements

The University of Michigan GreenSwapp Team would like to thank the CEO of GreenSwapp, Ajay Varadharajan, and his team for providing inspiration and guidance throughout the progression of this project. Additional thanks go to Dr. M'Lis Bartlett for her guidance of this project, as well as her academic and professional support. This research and the subsequent report would not have been possible without funding provided by the University of Michigan's School for Environment and Sustainability and the cooperation of our numerous

academic and industry partners. This includes those that partook in interviews and those that advised our data collection and analysis process.

Preface

Client: GreenSwapp

GreenSwapp is a Netherlands-based, for-profit business that is developing an algorithm to quantify carbon equivalent emissions of food products. Their mission is to, “track, reduce, and communicate the climate impact of your food products and recipes” (GreenSwapp). To achieve this, GreenSwapp gathered and condensed thousands of life cycle analysis (LCA) reports to provide an estimate of the emissions of all products within their comprehensive database ranging from simple (single ingredient) such as a tomato, to complex (multiple ingredients) products such as marinara sauce. As a result, the company’s database contains estimated emissions of each product accumulated throughout its life cycle. At GreenSwapp’s origin, consumers could utilize a phone application (app) to scan food products as they shopped for weekly groceries and generate a personalized profile through which they could employ carbon accounting to reduce their net emissions.

Carbon accounting, in relation to food, is a strategy of budgeting a specified quantity of emissions within a designated time, then only consuming products whose cumulative footprint falls below this quantity ("Carbon Accounting 101," n.d.). For example, consumers can utilize information about the carbon footprint of each of their grocery items to calculate their own weekly food-related emissions. If one is carbon budgeting, products with larger footprints such as hamburger meat, could be substituted by a vegan meat substitute with a smaller footprint. This action would ensure that the consumer purchased items with cumulative emissions less than the budgeted amount. Similarly, organizations higher up in the food chain, like food retailers, could establish a budget for their entire product portfolio, and in doing so choose to sell or not sell products based on their budgeted net food-related emissions.

In 2021, GreenSwapp transitioned from a consumer-focused company to a business-to-business model (B to B). This shift was intended to broaden the adoption of carbon accounting beyond consumers into corporations where the overall reduction of emissions would optimize their impact on food-related emissions. Through this model, businesses can receive comprehensive information about the carbon footprint of all food products within their portfolio. This information can then be utilized by these businesses to intentionally source, process, transport, or package their products in ways that reduce their net emissions.

The implementation of the European Union (EU) carbon cap and trade policy in 2005 supported the success of companies such as GreenSwapp, which are utilizing carbon accounting technology to reduce industry emissions. This policy established a carbon market across the EU

that limited the permitted net quantity of carbon emission equivalents released into the atmosphere per firm annually ("Establishing a Scheme", 2003). With the implementation of this policy, firms across all industries were mandated to either abate their emissions or purchase permits to continue emitting at their existing levels. This policy connected economic value to sustainable practices, resulting in the rise of social value as well. As a result, consumer demand for products with low carbon footprints rose. Through GreenSwapp, aggregate data through LCA's are used to provide consumers and companies with the information to fulfill this desire for sustainability reporting, and requirement for emissions reduction.

Project Origin & Application

GreenSwapp aspires to strategically target the U.S. food system in a way that could closely emulate their demand progression within the EU. However, the U.S. food system represents a significantly different social, political, and economic context for the adoption of industry-based carbon accounting. Therefore, GreenSwapp tasked the University of Michigan GreenSwapp team with assessing the feasibility of a federal carbon accounting mandate for food distributors and identifying alternative leverages for intervention. Mandating distributors to quantify and account their emissions, could theoretically circumvent historical aversion to federal emissions regulation policies, and instead utilize the market power of information to reduce net emissions.

The implementation of such a policy operates under the assumption that if food distributors were pressured to calculate their emissions, they would apply an equal amount of pressure on their industry partners to reduce. This is because a distributor's carbon footprint would cumulatively represent all emissions extending from the initial production to its current state in the distributor's inventory. Therefore, reductions throughout the production, processing, packaging, or transportation phases would be exemplified through lower product footprints at the distribution phase, therefore, making them in compliance with such a policy.

Due to the novel nature of carbon accounting as a strategy to reduce GHG emissions in the United States food system, additional research was needed to determine if such a policy would be feasible and effective within the context of the United States. This research sought to fill those informational gaps through both a comprehensive review of existing literature, as well as interviews with stakeholders within the US food system. The results of this project include a network visualization of the relationships between sectors, an analysis of the policy climate in relation to carbon accounting, and an informed list of alternative leverages for expanding the use and impact of carbon accounting, all in the context of the US food system. Utilizing this information, GreenSwapp, and other organizations promoting the expansion of carbon accounting throughout the US food system, can identify organizational action that optimizes their use of time and resources, while simultaneously maximizing their impact.

Disclaimer Regarding Interview Use

This research incorporates information from interviews with food system stakeholders. The interviews were used to understand current carbon accounting practices and how the interviewees think a carbon accounting mandate would impact their company or organization. Their information is woven throughout the report in the form of both paraphrasing and direct quotations. If a sentence cites an interview at the end, this means that the thought comes from that interviewee. For example, '"Major consolidation in our food system that and these pressures that are continuing to drive consolidation in these areas" (Advocacy Organization 2)' means that the person who was interviewed to represent this advocacy organization said this specifically. This how it is formatted when it is paraphrased: 'Our food system is consolidated, and governmental pressures are perpetuating further consolidation' (Advocacy Organization 2).'

Introduction

What are food systems?

Food systems are defined as the interconnected processes, systems, and players that deliver and influence food production, preparation, and disposal. Food systems can also represent a variety of scales: local, regional, national, international, and global. All scales include actors across the following sectors: producers, processors, distributors, consumers, retailers, and wholesalers (Von Braun, Afsana, Fresco, Hassan, & Torero, 2021).

Figure (1): This image signifies the function, and respective order of the food supply chain. As an example, producers cultivate and harvest a tomato crop. This crop is then sold to processors that will transform these tomatoes into a retail product such as marinara sauce. That sauce is then sold to wholesalers who package and sell the sauce in bulk to retailers. Retailers' self, and price the sauce for consumer purchase. Consumers then purchase the sauce and transform it into its final form, spaghetti. (Artistic rendering by Hannah Peplinski)

Producers represent those operating farms and growing or raising raw food products. Producers are responsible for planting, harvesting, and maintaining croplands; or rearing, feeding and harvesting products from animals (HPLE, 2017). Processors are companies that source ingredients from producers, then prepare them for retail. These processes can include manufacturing complex food products (those with multiple ingredients), as well as the packaging and labeling of all food products (HPLE, 2017). To ensure they retain their "fresh" shelf appeal, almost all food products sold through grocery stores or markets are considered processed ("Processed Foods and Health", 2023). While this processing does not always change raw products into completely new food products, they are sent through a multistep process for preservation, quality assurance etc. resulting in their final processed state ("Processed Foods and Health", 2023). For example, a tomato could be processed into a new product such as marinara sauce, or it could be processed to become a more preserved form of itself through the application of chemicals, waxes, or packaging. Retailers source food products directly from producers or processors, then market these products to public consumers (HPLE, 2017). Retailers range in size and structure from local farm stands to Walmart stores, but all represent the exchange of money for consumable goods. Wholesalers buy products from processors, or directly from producers, then sell them to retailers in bulk (HPLE, 2017). These products are ultimately re-sold

to public consumers at an elevated price to ensure retailer and wholesaler financial gain. Not all companies fit perfectly within one of these categories due to vertical integration, nevertheless the categories described provide a necessary outline for research on individual components of this system to be analyzed. The remaining sectors of food systems are not directly involved in the food supply chain but sustain significant influence over the content and functioning of the overarching system. These sectors include the government, research and data processing organizations, lobbyists, funding operations, and consumers all play a vital role in the state of the food system.

What is the problem?

The present-day global food system is responsible for 25 to 30% of total greenhouse gas emissions (Boehm et al. 2018; Ritchie, 2019). The breakdown of emissions resulting from each sector of the food system are displayed in Figure 2. The United States ranked amongst the top six emitting economies in the world along with China, Indonesia, Brazil, the European Union and India (Crippa et al., 2021).

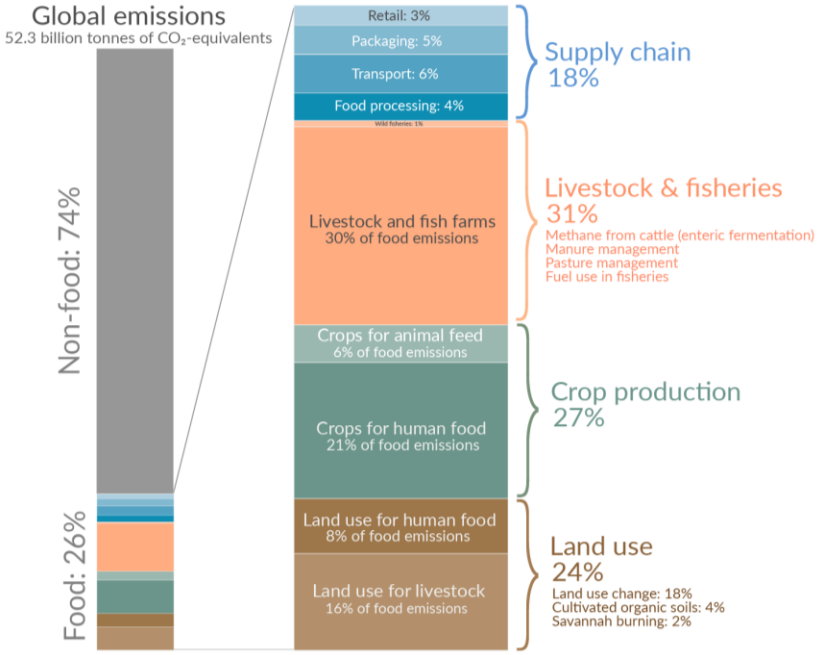


Figure (2): Global greenhouse gas emissions from food production, published in Science by Joseph Poore & Thomas Memecek (2018) "Reducing food's environmental impacts through producers and consumers."

These top emitters contribute to 51% of the global food related emissions. The United States is the only economy among them without a sustainability plan that explicitly calls for emissions reduction within the food system. While the recent passing of large climate legislation such as the Inflation Reduction Act and the Bipartisan Infrastructure Law have contributed substantial funding for federal programs to reduce the country's emissions in relation to energy and conservation, significant gaps remain. Without a specific plan and assigned regulating body

for the reduction of food related emissions, the country's 1.5 gigatons of carbon dioxide equivalents produced through the food system annually are going largely unchecked (Crippa et al., 2021). This is approximately 24% of the 6.34 gigatons total US emissions ("Inventory of U.S. Greenhouse Gas Emissions and Sinks", 2023).

Additionally, due to the $1.264 trillion dollars of US gross domestic product (GDP) specifically tied to agriculture, food, and related industries, it can be assumed that domestic system reform will have resounding effects on the functionality, sustainability, and security of systems globally ("Ag and Food Sectors and the Economy", 2023). Industrialized countries, such as the US, have drastically different configurations of how energy is used in agriculture and where GHG emissions are released compared to developing countries. Figure 3 calls attention to the difference between emission sources in industrialized versus developing and emulates that while emissions from land and production persist as the largest contributing factors of food systems, industrialized nations have significantly more emissions produced through the energy used and the waste produced.

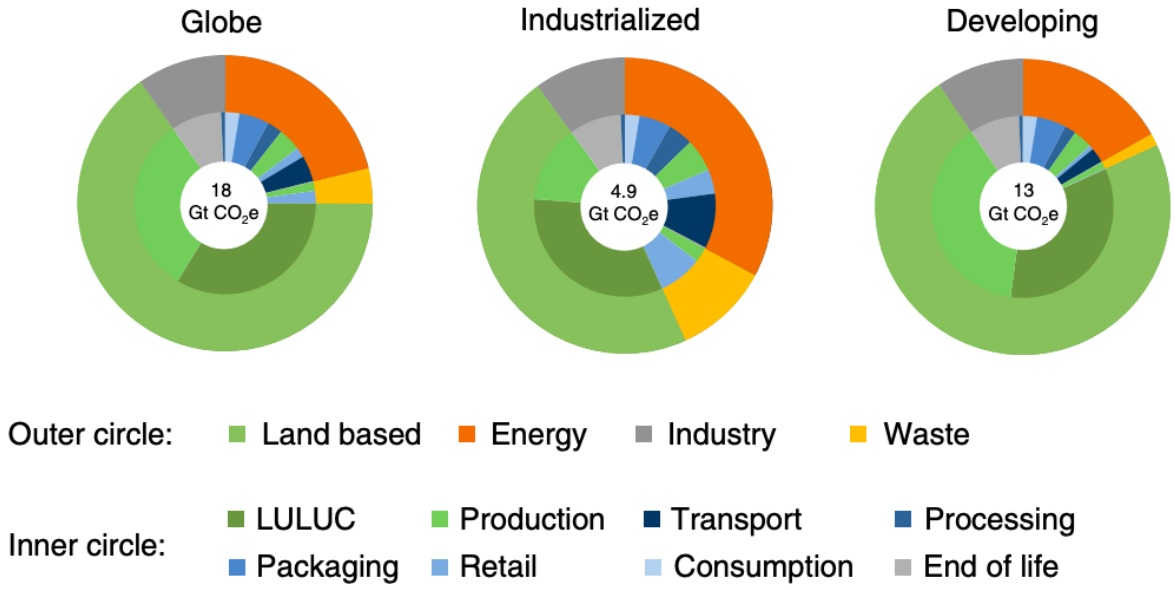


Figure (3): GHG emissions from the food system in different sectors in 2015. Total GHG emissions (including CO2, CH4, N2O and F-gasses) are expressed as CO2e calculated using the GWP100 values used in the International Panel for Climate Change. (Crippa et al., 2021)

Thirty-seven percent of GHG emissions from the US food system are attributed to energy, with 11% attributed to waste. Between 1990-2015 emissions from the retail sectors increased by 3.6 times. While emissions from land use, and food production are in some ways inevitable, substantial opportunity exists to reduce food related emissions associated with processes that occur later on in the food supply chain, such as through waste management, utilization of renewable energy for processing, eco-friendly packaging etc.

How did we get here?

In response to rising demands for food and economic revitalization, the US food "regime" was developed post WWII (Roberts, 2008). The initial intent to reduce food related insecurities that were perceived as a potential source for future wars (Roberts, 2008). The resulting "Green revolution" industrialized food production by providing federal funding through subsidies for food producers based on the quantity each produced (Roberts, 2008). As such, producers were incentivized to adopt practices that maximize output, such as mechanized cultivation practices, application of synthetic nutrients, and an expansion of land cover per producer (Roberts, 2008). Over time, these government incentives, paired with net producer profits through increased efficiency, has resulted in a food system model that no longer resembles the 'farm to table' linear model of the past.

New functions of the food system such as mechanization, mass marketing, genetic modification, chemical nutrient inputs, monocropping etc. largely disconnected the food system from natural functions. These transitions and their marketed benefits largely ignored their extreme negative externalities. Such externalities are represented through an associated degradation of ecosystem health as well as human health (Strier 2011). Greenhouse gas emissions exist as just one of these negative impacts. Emissions such as carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) are all produced throughout the food system, and all contribute to the acceleration of the greenhouse effect (Garnett, 2011). This naturally occurring phenomenon captures radiant energy from the sun to keep the planet at a habitable temperature, however vastly accelerates with the buildup of greenhouse gasses (National Resource Defense Council, 2019). This results in an increase in the global temperature that subsequently imbalances other global ecosystem functions (NRDC, 2019). Reductions in global anthropogenic GHG emissions is essential to restore and retain the ecological balance of the earth. Considering the notable contribution of food systems to these emissions, effective and lasting reduction strategies within this system must be identified.

Figure 2 depicts the net emissions from sectors of the global food system. The emphasis of this figure is on food production, as it is responsible for approximately 62% of the total emissions through food (Ritchie, 2019). These emissions are distributed across resource use, production practices, and enteric emissions, but excludes those represented by the supply chain (Ritchie, 2019).

Figure (4): Here is an example of a monocropped field being harvested in the United States. This form of industrial agriculture creates issues aside from carbon emissions such as pesticide use, deforestation, and soil depletion (Lewish, 2021).

Due to their predominant representation of food emissions (80-85%), producers have been historically targeted for food related emissions reduction strategies, for instance through the application of international funding, consumer pressure, and food emissions reduction targets (Joseph Poore & Thomas Memecek, 2018) (Brooks & Deconinick, 2019). However, action targeting a single sector of the food system, ignores the interconnectivity of the food system as a leverage in itself. Furthermore, the focus on the production fails to consider the limitations of the production sector that prevent large-scale adoption of sustainable agriculture techniques including economic, educational, and technological limitations, as discussed in the current state of carbon accounting for producers' section of this report. Factoring in political and economic feasibility, this project highlights opportunities for intervention, specifically relating to carbon accounting, that distribute the burden of emissions reduction across all food system sectors to optimize emissions reduction potential.

How do we solve the problem?

The basis for understanding carbon emissions is carbon accounting, a product of life cycle assessment (LCA). LCA is the study of a product's life within the linear production model (pictured below) and is a tool for "identifying or comparing the

Figure (5): This figure shows the life cycle of a product from material extraction to waste treatment/ recovery. These are the stages followed for a life cycle assessment. ("What is Life Cycle Assessment", 2020)

environmental impacts of a product" by assessing their interactions "with the natural environment" (Golisano Institute for Sustainability, 2020, para. 13). Examples of these interactions are air emissions, energy use, and land use. The goal of each LCA varies depending on the request, but typically each report will identify 'hotspots,' or areas where the environmental impact is significant (Golisano Institute for Sustainability, 2020, para. 20). Full life-cycle analyses are expensive and time-prohibitive because they can require a second party, so companies may only complete them on select products ("Limitations of LCA" 2018). According to the U.S. General Services Administration, an LCA has four main steps: define the goal and scope, conduct inventory analysis, conduct impact assessment, and interpret the results ("Conducting a Life Cycle Assessment," n.d). The paper "A life cycle assessment of the environmental impacts of a beef system in the USA," published in 2019, provides a detailed example of these four steps. The first step, creating a goal and setting the scope, guides the development of a research question and the scale of the project. The goal of the beef LCA was to "quantify the sustainability impacts associated with the production and consumption of 1 kg of consumed beef for a representative system in the USA" while the scope was the entire "cradle to grave" process (Asem-Hiablie et al., 2018, p 441). Defining the scope is important when aggregating life cycle data because it determines the inputs that need to be studied.

The next three steps of an LCA are the bulk of the analysis and include defining the inputs and measuring the outputs. An inventory analysis, the second step, details all inputs into the system while the impact assessment measures the outputs ("Conducting a Life Cycle Assessment," n.d). The challenge with the inventory step is acquiring the input data. For instance, the beef LCA required data from the integrated farm system, US Meat Animal Research Center, processors, primary data from retailers and restaurants, and consumer metrics from public data and research (Asem-Hiablie et al., 2018). The impact assessment - step three in the LCA - requires understanding all possible outputs, measuring them, and then aggregating them to one metric per interaction category ("Conducting a Life Cycle Assessment," n.d). From the same beef LCA, the impact categories were abiotic depletion, water emissions and use, energy demand, land use, acidification potential, human toxicity potential, air emissions, and solid waste impact. These impacts are then put into context in the results section - the fourth step (Asem-Hiablie et.al 2018). The results section also exposes leverage points for reducing

emissions. This information can then be used by other companies in their efforts to lower carbon emissions.

Since LCA's are so thorough, such results can be useful to companies working to lower emissions. Unfortunately, once a change is made to any of the product's inputs, the output calculations are inaccurate. Fortunately, for emission reduction efforts to be effective, an intricate, sensitive analysis may not be required. Knowledge of common carbon emitters can provide leverage points. For example, if multiple LCAs of eggs were aggregated and it was found that one of the main contributors to the overall emissions was chicken feed, this would indicate a potential reduction point.

The cost, time, and sensitivity of traditional LCAs make machine learning an important tool in reducing carbon emissions in the food industry. GreenSwapp is one company working to aggregate LCA data. The algorithms and calculations can assist in understanding the impact of more products, both faster and cheaper, with the end goal being a change in how products reach the shelves, and thus a reduction in emissions.

Carbon accounting is when LCA is used by companies and organizations to understand and manage their carbon emissions. There are three scopes to a company's carbon footprint. Scope 1 emissions are the emissions that are directly from the company's operations and are in its control, such as gas for company vehicles ("Carbon Accounting 101," n.d.). Scope 2 emissions are "indirect" emissions from a company's operations, but are not in their control, such as energy purchased to power factories ("Carbon Accounting 101," n.d.). Scope 3 emissions are the supply chain emissions of the purchased goods, such as the production emissions of food products bought by a processor ("Carbon Accounting 101," n.d.). Scope 3 emissions are, on average, 5.5 times higher than scopes 1 and 2 emissions ("What is Carbon Accounting?" n.d.). Detailed data assists companies in this effort to reduce emissions.

> Granular data on where emissions are coming from helps direct the organization's emissions reduction efforts. In addition, ongoing tracking of GHG emissions provides a quantified feedback loop to track if initiatives are achieving the desired outcome ("What is Carbon Accounting?" n.d. Para. 9).

Fortunately, many companies do have a reduction program. One reduction program that has an influence on the global food supply chain is Walmart's Project Gigaton. This initiative's goal is to "reduce or avoid one billion metric tons of greenhouse gasses from the global value chain by 2020" ("Project Gigaton," 2022). This project is set up to achieve this by having companies, NGOs and other stakeholders participate in "setting targets and taking science-based, measurable action to reduce emissions across six areas critical to reaching zero emissions: energy use, nature, waste, packaging, transportation, and product use and design" ("Project Gigaton," 2022). About 5000 total suppliers have signed up and are participating ("Supplier Recognition - Project Gigaton" n.d.). Without access to accurate carbon emission information from LCAs and carbon accounting, this initiative and the goals at other companies would not be possible.

How this research contributes to the solution

This project began with the question "given that the global food system contributes 25-30% of net carbon emissions, what is a strategy to influence the system components and primary actors to significantly reduce carbon emissions in the US food system?" To that end, researchers examined the feasibility of a federal carbon accounting mandate within the United States and sought to discover potential barriers this policy could face, as well as alternative leverages to affect system change, and reduce net emissions of the US food system. While it is undeniable that the global food system is highly complex and interdependent, identifying actions and actors that can be utilized as leverages specifically within the United States was necessary to limit the scope of this project, and ensure maximized depth of research within a limited timeframe. Furthermore, the United States was identified as a market with significant food related GHG emissions, without an existing reduction plan. Due to the interconnected nature of the global food system it can be expected that action within the US food system will have resounding effects on systems globally.

To comprehensively understand the feasibility of this mandate, researchers needed to conduct an in-depth analysis of the state of carbon accounting in the US food system, as well as the policy landscape this mandate would be implemented within. To determine alternative leverages for intervention, researchers also needed to analyze the relationship dynamics within sectors across the US food system. Five themes were utilized throughout this research process to collect and analyze data: 1) the current state of carbon accounting, 2) internal mechanics of decision making, and adoption of sustainability policies, 3) challenges to the adoption of related policies, 4) relationships with other sectors in the system, and 5) future projections of carbon accounting in the food system. The organization of this project is highlighted in Figure 6.

The identified alternative opportunities for intervention extend beyond a federal carbon accounting mandate, and into more feasible actions considering the US context. These include a state-level mandate for carbon accounting, the utilization of LCA data for targeted reductions, a federal mandate for carbon labeling, investments in carbon accounting data development and regulation, and, finally, amending the Healthy Eating Index and Supplemental Nutrition Assistance Program (SNAP).

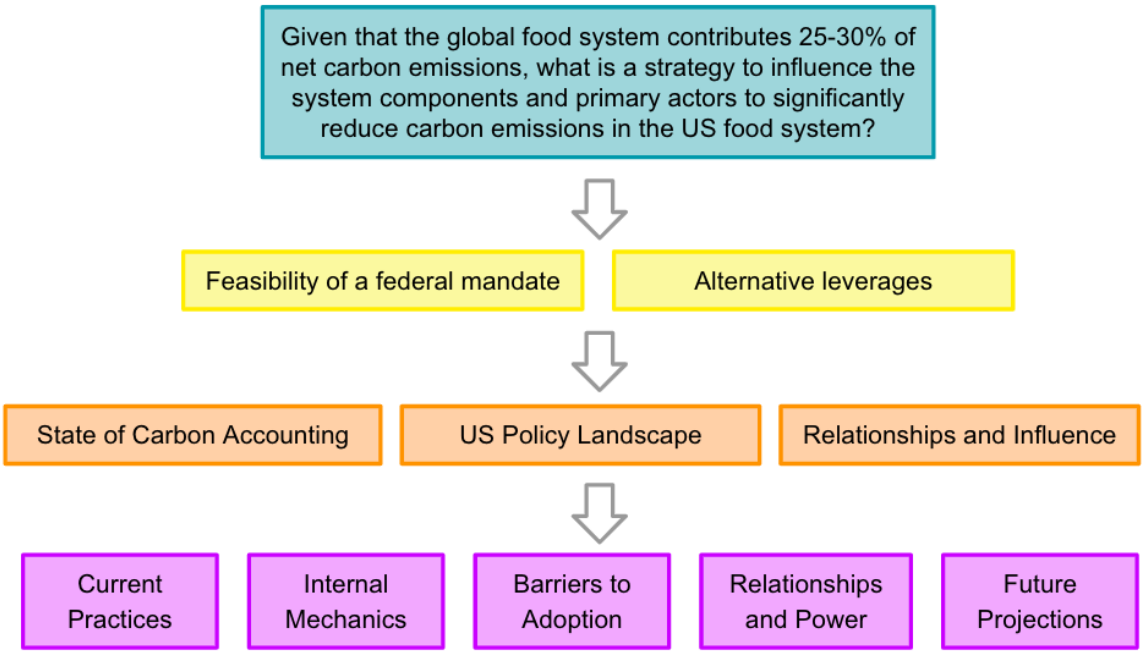


Figure 6. A graphic display of this project's development. This project began with the research question at the top in blue. This was followed by the identification of 2 project deliverables in yellow. To inform these deliverables, researchers collected, processed and analyzed data relating to 3 research topics in orange. The processing of this data was conducted utilizing the 5 themes in purple.

Methods

This project explored the feasibility of a federal carbon accounting mandate for food distributors and identified alternative leverages to utilize carbon accounting as a tool to reduce net emissions within the United States food system. To that end, this study asks, given that the global food system contributes 25-30% of net carbon emissions, what is a strategy to influence the system components and primary actors to significantly reduce carbon emissions in the US food system? To approach this question the team 1) identified the primary sectors of the US food system, 2) conducted a literature review of the current state of carbon accounting including US policy climate in relation to carbon accounting, historical action taken, and influential actors, 3) interviewed three or more stakeholders in all identified food system sectors, and 4) performed a qualitative analysis on interview data. It is important to note that due to the novel nature of carbon accounting as an emissions reduction tool, research was conducted on both overarching emissions reduction strategies, as well as carbon accounting specifically. While the direct translation of elements such as the potential for impact, and timeline of adoption may not be possible, the analysis of related policies can provide valuable information for elements including, but not limited to, internal decision structures, and future projections.

From this data researchers drafted this whitepaper including a network visualization of the United States food system, a comprehensive analysis of the feasibility of a federal carbon accounting mandate, and a list of recommendations for alternative strategies to expand the adoption of carbon accounting strategies as a tool to reduce emissions within the US food system. A visual representation of the progression of this project is displayed in Figure 7.

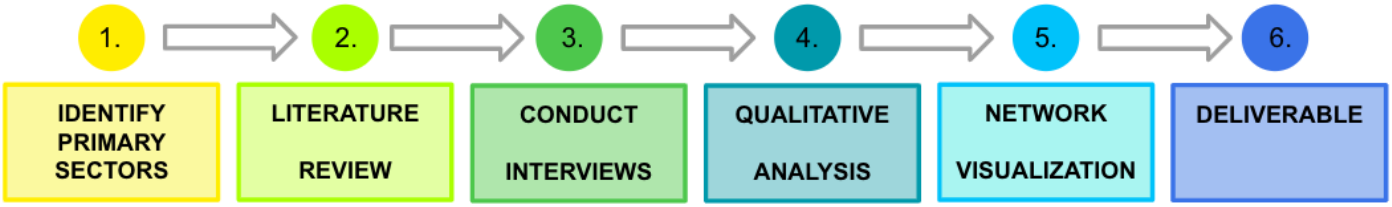


Figure (7): Visualization of the methods of this research, and the progression through which this project was completed.

Primary Food System Sectors Examined

Based on preliminary research about food system dynamics and supply chains, eight key sectors were identified to focus on for the report, identified in Figure 8 (Brouwer et al, 2020; HPLE 2017; HPLE 2020; Sobal et al., 1998). These sectors guided decisions about literature reviews, selection of interview respondents and form the basis for the organization of the report.

Producers	Person or organization directly engaged in the rearing of agricultural products such as crops, or livestock ("Agricultural Producer", n.d.)
Processors	Companies that source ingredients from producers and transform them into food products to sell (Burger, 2020).
Wholesalers	Companies that procure food products from processing companies, package, then resell them to retailers, food service locations, governments, or other wholesalers ("Retailing & Wholesaling", n.d.)
Retail & Procurement	Grocery stores, restaurants, universities and other entities between wholesalers and consumers that buy food for their consumers
Consumers	The general US public, food purchasers for eating purposes
Research & Data Processing	Researchers who generate or aggregate Life Cycle Analyses that can be utilized for carbon accounting. Can be nonprofit, for profit or government entities.
Advocacy Organizations	For-profit, non-profit, or non-governmental organizations with food centered missions
Government	Local, regional, state, federal, and international governing bodies and officials that have regulating power over US businesses, organizations, and populations
Lobbies	Non-government entities that communicate directly with officials in the executive or legislative branch of government to influence legislative or administrative action (National Council of State Legislators, 2021)

Figure (8). Definitions of all sectors that researchers analyzed data within and interviewed. Lobbies are the only exception, in that they were found to be an influential sector but were not directly interviewed.

Literature Review

To gain a comprehensive understanding of the state of carbon accounting within the United States food system, a literature review examining carbon accounting practices and policies within the food system was conducted. This included those policies in current practice, as well as those historically implemented, or proposed, but ultimately failed due to operational challenges. This research covered all sectors directly involved in the food supply chain, including producers, processors, wholesalers, retailers, and consumers. Additional analyses were conducted related to the impact (influence) of research organizations, and advocacy organizations. These sectors are not directly involved in the food chain but maintain a significant influence over the operations within the system as a whole. Information gathered from these sectors included the prevalence of carbon accounting strategies, the success or failure of related policies within these sectors, and the documented barriers preventing the broad-scale adoption of carbon accounting. Due to research limitations, consumers were not directly researched, instead, peer-reviewed articles on consumer behavior in relation to food consumption were compiled and analyzed.

Additionally, researchers conducted an in-depth policy analysis, and government sector review at the municipal, state, national, and international levels. This research developed an understanding of the policy climate within which a carbon accounting mandate would be implemented. To accomplish this, researchers reviewed policy proposals and existing legislature, existing peer-reviewed policy analyses and research papers, and legislative reviews. The government sector analysis at each level also informed researchers of who the primary actors and stakeholders are, and what their influence may be on the success or failure of a carbon accounting policy implemented at each level.

Stakeholder Interviews

Semi-structured interviews were conducted with at least three people within sectors: producers, wholesalers, retailers, consumers, advocacy organizations, research and data processing, and government. Six interviews were conducted in the processor sector, with three individuals representing regional processors and three representing vertically integrated processing corporations. In total, 28 virtual interviews were conducted, transcribed, and analyzed. The semi structured format controlled the trajectory of the conversation and opportunities to ask follow-up questions unique to the participant (Rubin & Rubin, 2012). Furthermore, the interviews allowed for targeted data collection related directly to the core themes of research, as well as the collection of supporting data.

The interview questions were crafted to expand upon information that the literature review was unable to adequately address. These questions covered five themes: 1) the current state of carbon accounting, 2) internal mechanics of decision making, and adoption of sustainability policies, 3) challenges to the adoption of related policies, 4) relationships with other sectors in the system, and 5) future projections of carbon accounting in the food system.

The current carbon accounting theme explored how, or if, carbon accounting is used within different sectors, and if it is utilized as an emissions reduction tool. The internal mechanics theme identified the internal motivations, and decision-making structures of organizations to enact carbon reduction policies. These questions addressed economic, social and political influence, as well as the decision-making hierarchies within the sector. Questions in the challenges theme inquired about barriers preventing the same entities from adopting carbon accounting as an emissions reduction strategy, such as available resources or political opposition. Relationship theme questions focused on establishing an enhanced understanding of the power dynamics across sectors. Finally, the future projection's theme gathered additional insight on how different sectors predict the influence of carbon accounting within and across sectors for emissions reduction, and economic well-being.

Utilizing these five themes, researchers generated a list of 10-15 questions for each sector of the food system. Half of the questions were directly related to the four themes, while the remaining 5-10 questions were utilized for the collection of supplemental information specific to the sector. Each list of questions was reviewed and edited by at least one other researcher to ensure that all themes and informational gaps from the literature review were addressed.

The 28 interviewees were chosen to best reflect the diversity of stakeholders within each sector in relation to size and scope of influence. Stakeholders that had publicly stated sustainability goals were also prioritized for interviews. Rubin & Rubin (2012) note that this group of stakeholders can provide insight into logistical leverages through which carbon accounting can become an emissions reduction strategy (Rubin & Rubin, 2012). Interviews were conducted virtually, and all participants were assured complete anonymity. After transcription, each interview was anonymized for analysis. Maintaining confidentiality was important for protecting individuals who reported information about the internal and external dynamics of stakeholders but were not given legal consent to speak on behalf of their associated organization. Interviews ranged from 30-90 minutes and included 1-2 researchers and 1 professional stakeholder.

To represent the consumer perspective, interviews were conducted with experts that could speak to consumer behavioral patterns within the US food system as a whole. This included experts in urban planning, psychology, and market analytics. This method was chosen for time efficiency, and to reduce research biases through consumer data collection. Interviewee information is summarized in table (x), including what sector the interview represented, the scope that their organization covers, a brief description of the organization(s) they are associated with, as well as the reference code used throughout this report.

Represented Sector	Scope of Influence	Associated Organization(s)	Reference Code
Producer	Local	Grocery store with an emphasis on local food and farmers	Producer 1
Producer	International	Multinational processing conglomerate with vertically integrated producers	Producer 2
Producer	Regional	Industrial farmer operating an x acre farm with soybeans, sugar beats, corn and cattle	Producer 3
Processor	International	Multi-national food product corporation based outside of the US, but with significant influence in the US market	Processor 1
Processor	Regional	Food processing company based regionally in the northwestern United States	Processor 2
Processor	International	A multinational corporation	Processor 3
Processor	National	Vegan food producer with 2022 annual revenue between 65-70k	Processor 4
Processor	International	A multinational corporation producing and distributing food and beverage products	Processor 5
Wholesale	International	North American food product wholesaler. With annual revenue ranging from $15-$20 billion	Wholesaler 1
Wholesale	International	Agribusiness food supplier, servicing 20,000-25,000 customers globally in over 60 countries. Primarily distributes raw ingredients, sourced from small to industrial farms	Wholesaler 2
Wholesale	National	Wholesale food supplier providing a variety of processed and fresh products nationally. Products are sourced both domestically and internationally from predominantly industrial producers. Estimated to provide for 15-20% of the annual foodservice market in the US.	Wholesaler 3
Retailer	Local	family-owned restaurant, deli, market, and catering service based in the Midwest	Retail 1
Retailer	Regional	Executive chef at Michelin-starred metropolitan restaurant group	Retail 2
Retailer	National	Former researcher for national procurement initiative	Retail 3
Retailer	International	Researcher advising international specialty food retailers	Retail 4
Consumer Expert	National	Professor in Planning at an R-1 university within the US with a focus area on food systems development and disparities.	Consumer Expert 1
Consumer Expert	National	Founder and Executive Director for non-profit researching relationships between people and food. This data is then utilized to inform policy makers on sustainable food policy solutions.	Consumer Expert 2
Consumer Expert	National	Principal investor in a global investment firm striving to accelerate the transition of sustainable food systems. Previous roles in sustainable food-centered NGOs and research centers.	Consumer Expert 3
Consumer Expert	National	A for-profit organization that employs market strategy, culinary innovation, and consumer engagement to reduce carbon emissions at restaurants, grocery stores, and other clients	Consumer Expert 4

Data Researcher	N/A	Biologist studying international agricultural development and transformation	Data Researcher 1
Data Researcher	N/A	Research specialist and consultant for sustainable food systems	Data Researcher 2
Data Researcher	N/A	Professor and researcher at a midwestern public institution specializing in the food system and labeling.	Data Researcher 3
Advocacy Organization	International	An organization dedicated to serving clients, typically corporations, who want to understand and manage their carbon footprint	Advocacy Org 1
Advocacy Organization	International	Non-profit organization focused on government overreach and corporate accountability with an emphasis on the food system.	Advocacy Org 2
Advocacy Organization	National	Environmental research institute based in California	Advocacy Org 3
Government	Local	Mayor appointed food policy council in the West	Government 1
Government	Local	Mayor of midwestern city	Government 2
Government	Local	Sustainability Director of a midwestern city	Government 3
Government	National	The interviewee is a Legislative Assistant to a US Senator in southwestern US	Government 4

Table (1): Summary of all interviews conducted through this research project. The column represented sector identifies what sector of the food system the interview was utilized to collect data on. The column scope of Influence identifies at what scale the interviewees associated organization exists within, or the scale to which they predominantly spoke to the state of the food system. The column associated organization(s) summarizes the interviewee, or organization that the interview was conducted to represent, with liberties taken on behalf of researchers to summarize associated information with the purpose of preserving anonymity. Finally, the column reference code is provided as context for references to interview data utilized to support arguments constructed in the remainder of this report.

Qualitative Analysis

Analysis of the interviews was conducted utilizing a qualitative data analysis protocol with a set of a priori codes and subcodes to identify main themes across sectors (Miles et al. 2014). Based on Miles et al. (2014) our analysis codes were “researcher-generated construct[s] that [symbolize and attribute] interpreted meaning to each individual datum for later purposes of pattern detection, categorization, theory building, and other analytic processes” (NEED PAGE NUMBER). The codes generated for analysis were descriptive, providing a general category or topic that related to the five key themes. Analysis began with a provisional coding book based on the key themes of the interview questions and were modified as needed throughout analysis (Miles et al., 2013). The primary codes were produced prior to the interviews and were directly related to the core themes (see appendix). The subcodes were generated as they emerged from the interview analysis. A codebook was created based on the primary codes and subcodes and was used by researchers to identify the codes within interviews.

The interview information was used in the network analysis and to inform further sections - results and discussion. The interviews were used as support and provide context and for many of the topics regarding a federal carbon accounting mandate. As a disclaimer, these are not facts, but are used as evidence and provide an expert opinion on the subject matter. Interviewees were chosen with care and can be trusted experts but should not be taken as certainty.

Network Visualization

Interview information from questions specifically focusing on relationship and influence dynamics were utilized to inform a network visualization. This visualization method was based on the network analysis methods in the Towards Data Science article 'What is Network Analysis?' that provides a comprehensive explanation of network analysis (Mengsay Loem 2021). These methods, however, were altered to accommodate the limitations of this project. In this study, the data collected from interviews was not extensive enough to code a complete network analysis, so this step was eliminated. In the visualization, the five primary sectors representing the food supply chain: producers, processors, wholesalers, retailers, and consumers; as well as the three primary, external sectors: data and researchers, advocacy organizations, and United States government are all represented by spheres. Additional spheres representing lobbies, and international government were deductively added. Lobbies and international governments represent sectors that were identified as having significant influence on the actions of the primary sectors but were not explicitly interviewed through this project. These spheres were then connected in accordance to influence dynamics identified through a coded qualitative analysis of the interview transcripts.

The primary inductive code used for this analysis was "relationships." The subsequent deductive codes, "sectors you influence" and "sectors that influence you" determined where the vector representing influence originated and ended. The origin of influence determined the directionality of the influence vector, with influence extending outward from the identified source. Due to the multiplicity of influence vectors representing the same points of origin and reception of influence, a count of each relationship mentioned was recorded. Because these records of influence extended from one sector to another, they were determined to represent inter-sectoral influence. Interview excerpts expressing the origin and reception of influence within the same sector were recorded and counted separately and determined as intra-sectoral influence. The strength of influence of individual sectors in the food system was calculated by summing the count of influence vectors that originated from that sector.

Relationships identified, between and within sectors of the food system, represent a variety of influential factors including purchasing pressure, political regulation, and market pressure. All identified vectors of influence, with their points of origin, reception, and a summary of the interview excerpt they were coded from, can be found in table (x).

Results

Qualitative Analysis

The most important themes, illustrated in Figure 9 are detailed here. For a summary of all themes and codes, please see Appendix B**.** Qualitative analysis of sector interviews showed that significant trends emerged when excerpts were grouped according to codes. Ten codes appeared in interviews across either all eight or seven of the sectors interviewed and these ten codes heavily inform the discussion of this report. These ten codes also accounted for 50% of total excerpts, further supporting their role in guiding the discussion. When looking at the interviews along sector lines, there were no codes that were disproportionately represented within a specific sector. Instead, respondents within sectors and important things to say about a variety of topics. There were no codes that appeared in every interview done with processors, consumer experts, advocacy organizations, or processors, and the codes that were present in all of interviews with data researchers, government, retail, and wholesalers were not different from the codes that were most prevalent across sectors as a whole.

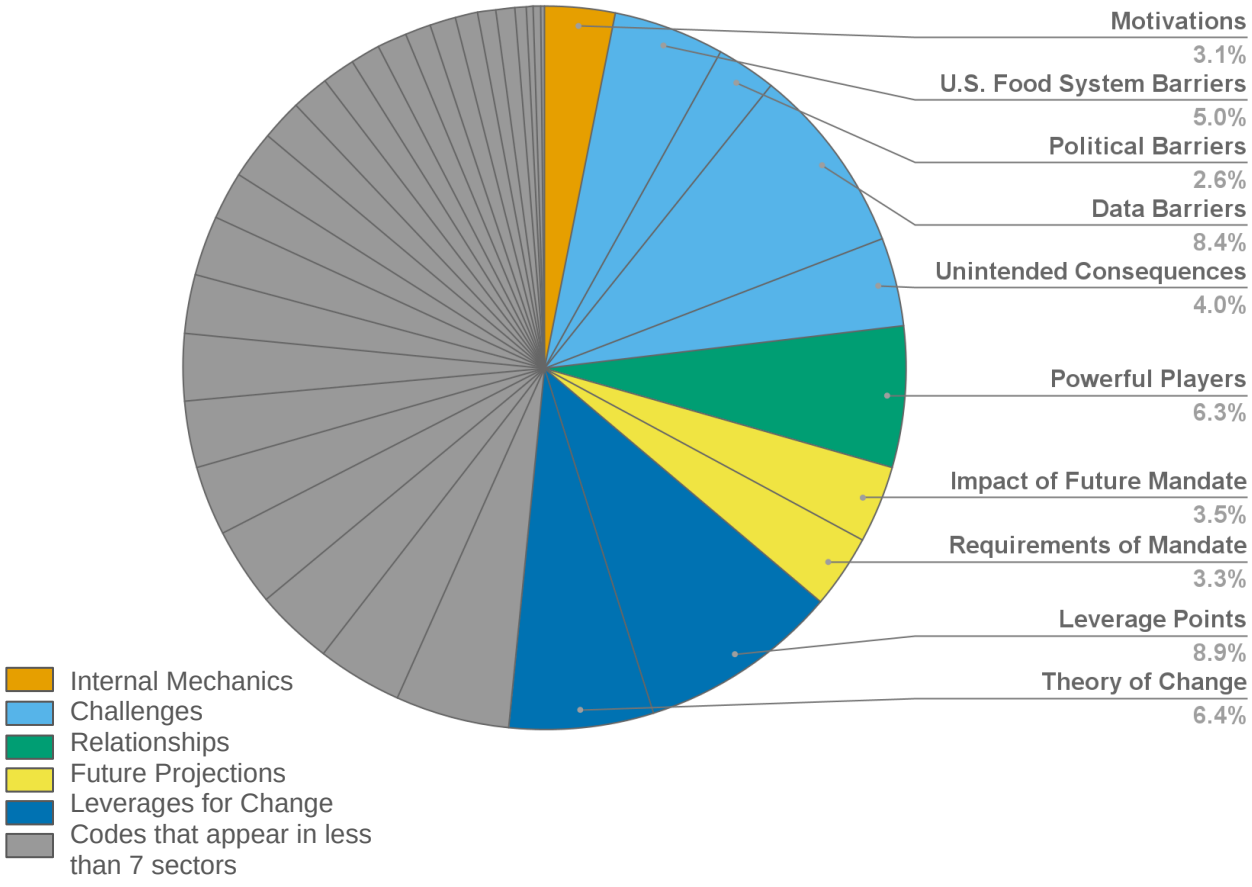


Figure (9). The ten most prevalent codes in the qualitative analysis, comprising 51% of total coded excerpts. Legen shows the theme each code is attributed to.

The most prevalent codes appeared across the themes of internal mechanics, challenges, relationships, future projections, and leverages for change. The theme of carbon accounting was the only one to not be discussed in seven or eight sectors. This is likely because familiarity with carbon accounting varied significantly across sectors, with some such as processors having a high level of experience and others, such as government having little or none.

Within internal mechanics, the code "motivations" was the most important. The dominant topic brought up here was how important it is for there to be a strong financial case for introducing sustainability policies and sectors in the supply chain must perceive that their customers –whether that is another sector in the supply chain, such as wholesalers or the end consumer– value sustainable practices and information about carbon emissions. Without these two components, respondents did not think it was likely that there would be significant progress toward implementing carbon accounting policies.

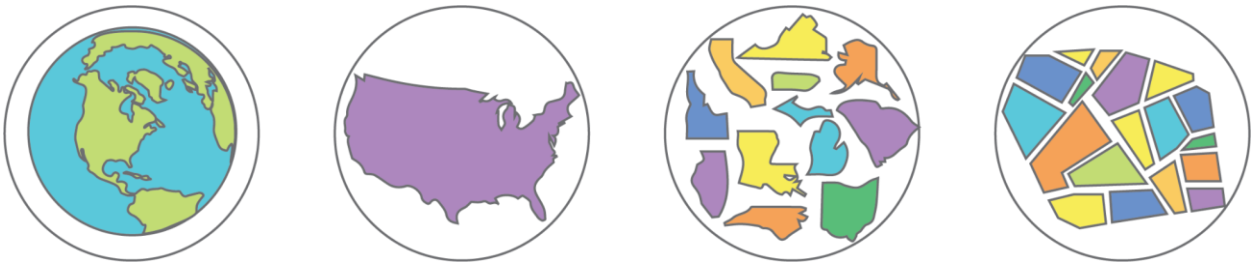
Four codes about the challenges of carbon accounting were present across seven or eight sectors: US food system barriers, political barriers, data barriers, and unintended consequences. In US food system barriers, the complexity of the food system, consolidation of large agribusiness firms, the lack of a centralized agency to oversee LCA data, and not having any current accountability mechanism for sustainability were noted throughout interviews. The acknowledgement of the complexity of the US food system across sectors serves to support the systems narrative that drives this report and the leverages highlighted as recommendations. Political barriers, specifically the influence of lobbies and industry on the legislative process were seen as a barrier in all eight sectors and contribute to the analysis of the role of lobbies later in the report. Data barriers to a carbon accounting policy were also noted across all eight sectors. Data barriers are explicitly addressed in the discussion and inform the recommendations for alternate leverages. Unintended consequences inform discussion of opportunity costs, greenwashing, and equity. Multiple respondents specifically had concern about the unintended consequence of carbon accounting policies increasing consolidation of the food system because it places a burden on smaller producers and business as larger entities have more resources for complying with regulations.

The relationship code of powerful players relates to the complexity of the food system and the power that industry has through consolidation, vertical integration, and lobbies, and informs the assessment of the policy climate for adopting carbon accounting measures and the feasibility discussion. Excerpts in this code related to how respondents saw the relationships of other actors within the food system, rather than the power dynamics that were at play in their individual sector, which informed the network visualization.

In future projections, many respondents had opinions about the codes impact of a future mandate and requirements of a mandate. Many respondents saw drawbacks to a mandate, overlapping with unintended consequences and equity concerns. However, processor, consumer experts, and government respondents also saw significant potential for a mandate to catalyze action among businesses. Excerpts about requirements of a mandate focused on accessibility of data and the importance of a centralized agency overseeing carbon accounting.

Leverages for change is the code that emerged after our interviews were complete. Even though many sectors were not familiar with carbon accounting or saw significant barriers to implementation, respondents across sectors did see ways that data could help achieve sustainability goals, even if a federal mandate was not feasible. In addition to being present in all eight sectors, the code leverage for change was also mentioned by the largest number of interviewees, 20, and made up the largest percentage of all excerpts (8.9%). The points brought up in this topic by respondents heavily informed the discussion of how carbon accounting can be leveraged without relying on a federal mandate. The theory of change code demonstrated that even though respondents had differences in how they thought change would happen within the US food system, change was seen as possible and, among some, inevitable. As the theme of leverages for change emerged through the process of analysis, it created momentum for the discussion and development of alternative leverages for intervention.

Policy Climate for Adopting Carbon Accounting Measures



(Artistic rendering by Hannah Peplinski)

As both a primary stakeholder and influential actor, government agencies represent significant opportunities and challenges for the implementation and ultimate success of carbon accounting strategies. Policies actively regulating or procuring sustainable food products, can expand carbon accounting as a tool to reduce emissions within the US food system. It is important to note that because of the interdependent nature of governing, leverages at one scale will likely have influence over the action and practices of others. For example, federal policies could require regulation at both state and municipal levels, as well as have profound influence on reduction at all levels. Therefore, while this report largely separates each level of governance, many leverages exist across multiple scales but are being highlighted within the level through which it is either most feasible or salient. This section of the report breaks down historic and existing policies and programs relating to emissions reduction within the food system at the international, national, state and local level. This information is then utilized to identify leverages for policy adoption that explicitly call for carbon quantification and accounting strategies.

To understand the current political and economic climate that carbon accounting- and related policies exist within, it is important to first understand who the primary actors are within each level of US governance and identify whether they will progress or hinder the policy's adoption. This analysis included information collected through the literature review combined with data collected from interviews. Information derived from this analysis was informed by recommendations regarding the political feasibility of a federal carbon accounting mandate within the US, as well as the identification of alternative leverages to expand the use and impact of carbon accounting within the US food system.

International Policy

"Before you finish eating breakfast in the morning, you've depended on more than half of the world." Martin Luther King Jr., 1967

While this quote and the sermon that followed called attention to the interconnected nature of global populations, its meaning can be further extended to highlight the interdependence and influence of global economies and international organizations on one another. Although the United States produces much of the food consumed by its population, 12-13% of food and beverages consumed within the United States are imported ("Close to 90 Percent, 2018). Therefore, actions by international governments and powerful actors affecting the sustainability of global food practices can be expected to have a significant impact on sustainable food consumption and distribution domestically. While carbon accounting and sustainability goals are not one in the same, they both maintain the goal of reducing net emissions, and achieve this through the application of scientific data. Therefore, this report assumes that actions on behalf of sustainability would have subsequent effects on the salience and applicability of carbon accounting. Carbon accounting is not a highly salient tool for emissions reductions within the present-day US. However, the salience of international utilization is vital in understanding the full landscape that US intervention strategies will be interacting among. Furthermore, international actors and policies have significant potential to influence the popularity of carbon accounting within the US. This report calls attention to notable actors, policies and intergovernmental panels that can be reasonably expected to have a significant influence on the speed and scope of related actions within the US.

International Policy Landscape

International commitment and pressure relating to large-scale emissions reduction largely originates from the Paris Climate Agreement adopted in 2015 ("The Paris Agreement", n.d.; NRDC, 2021). The goal of this agreement was to hold the increase in the global average temperature to well below 2 degrees C; a goal that is unlikely to be achieved without substantial reconfiguration of the current global food system. In an attempt to hold affluent countries

accountable for their disproportionate contributions, this agreement was the first of its kind to distribute emission reduction targets unequally (Clemencon, 2016). Upon rejoining this agreement in 2021, the Biden Administration committed to achieving 50-52% emissions reduction compared to the country's 2005 level ("Fact Sheet", 2021). Article 6 of the Paris Agreement detailed the structure of an international carbon trading market, fueling international quantification efforts. However, as highlighted in an interview with Advocacy Organization 2, "The people pushing this don't really care whether or not the numbers are right. What they care about is having a firm number that they can all agree on, so they could sell it for [profit] [to other countries]." Additionally, these commitments, associated policies and targeted emissions reduction strategies do not explicitly name the food system. However, targets through agriculture, transportation and industrial processes all support reductions in food-related emissions ("Fact Sheet", 2021). Due to the voluntary nature of this agreement, substantial global pressure is a necessary additive to these promises to hold administrative actors within the US to these commitments.

The United Nations Food Systems Summit of 2021 was the world's first step toward reconfiguring climate targets to include a food systems approach. Including nearly 300 commitments from 183 countries, this summit highlighted 3 primary targets: "nourishing everyone for health and wellbeing," "producing in harmony with nature," and "inclusive, transformative, and equitable recovery for the 2030 agenda." The Food and Agriculture Organization (FAO), the International Fund for Agricultural Development (IFAD), and the World Food Program (WFP) have been assigned to lead a coordination hub to progress work from the summit by working directly with partners within and across each country. Considering how large and complex food systems are, this accountability and regulation are vital for the success of this agreement (Covic N., Dobermann A., et al., 2021). One strategy committed countries are expected to employ is the shifting of sustainable consumption patterns by building enhanced consumer demand for sustainably produced food and strengthening the local value chain (Food Systems Summit 2021). Additionally, many involved countries are expected to promote nature-positive production by optimizing environmental resources utilized in food production, processing, and distribution. The goal of these actions is to limit negative impacts on natural ecosystems and reduce GHG emissions (Food Systems Summit 2021).

Carbon accounting exists as a tool in the intersection of many of the goals. Quantification strategies provide enhanced information that can be utilized by consumers to make informed sustainable purchasing decisions, in turn, this information supports the reduction of emissions through carbon accounting. The UN Food Systems Summit therefore exists as an unofficial extension of the Paris Climate Agreement with both enhanced accountability strategies and a focus on food systems as a pathway for emissions reduction.

International Influential Actors

The Intergovernmental Panel on Climate Change (IPCC), United Nations Environment Program (UNEP), the Consultative Group on International Agricultural Research (CGIAR), and the Forum for the Future (FFF), can be expected to add additional pressure to the US climate and actors within food systems. The IPCC provides global governments with data that can be utilized in the development of climate change policies (IPCC, 2022). IPCC's work can be divided into 4 working groups: I-the physical science basis of climate change, II-climate change impacts, III-adaptation and vulnerability, and IV-mitigation of climate change. Working group III works most directly with carbon emissions reduction strategies as they study mitigation technologies and economically viable sustainability pathways for emissions reduction. While IPCC does not provide specific policy recommendations, their research lays the foundation for policy development and proposes optimized action pathways. Their Task Force on National Greenhouse Gas Inventories (TFI) founded in 1998 was established to support the National Greenhouse Gas Inventory Program, to "develop and refine an internationally-agreed methodology and software for the calculation and reporting of national GHG emissions removals and encourage the widespread use of this methodology by countries participating in the IPCC" ("Task Force", 2023, para. 5). This research and technology will develop and standardize emissions calculations that serve as the base of carbon accounting strategies. IPCC provides the information necessary for policies requiring reduction and ensures that the data behind associated accounting algorithms are both available and accurate. As implementation and regulation strategies are only as strong as data they rely upon, such actions are vital for feasible and effective carbon accounting strategies. Through stakeholder interviews, IPCC

The United Nations Environment Program maintains the "authority to set environmental agendas, promote sustainable development strategies, and serve as authoritative advocates for global environments" (United Nations Environment Program). This panel collaborates directly with 193 member states, representatives and business leaders to identify feasible and impactful pathways for policymakers to combat the impacts of the climate crisis. In collaboration with the World Wildlife Fund (WWF), EAT, and Climate Focus, UNEP develops annual, comprehensive reports calling attention to the impacts of anthropogenic activities on the global environment. One focus area of these reports, as well as the associated policy recommendations, is that of food systems. These food system recommendations span from emissions reduction to habitat loss and serve as a tool for environmentally focused policymakers to advance their impact. This panel, and its established network of partners, played a key role in developing globalized recognition of climate change as a global economic threat, as well as a place for broad-scale political action (Andresen, S., 2007). Therefore, with the continued advancement of its associated research and network, one can assume that the influence of UNEP over national climate policy will also advance.

UNEP also maintains relationships with research institutions, in addition to conducting its own policy and economic analyses. However, more closely aligned with the development of global climate change research and solutions is the Consultative Group on International

Agricultural Research (CGIAR). CGIAR is also a prominent actor in the advancement of global emissions but focuses specifically on advancing sustainability within food systems. With 8,000 employees conducting research in more than 100 different countries simultaneously, CGIAR represents the world's largest global agricultural innovation network (CGIAR, "How We Work"). CGIAR projects with the greatest potential for influencing the salience of carbon accounting strategies are the International Food and Policy Research Institute (IFPRI), Policies Institutions and Markets, and Agriculture for Nutrition and Health. IFPRI has partnered with 40 peer organizations to conduct science-based monitoring to analyze both the effect of climate change on global agricultural systems, as well as feasible policy solutions for mitigation. Within this program, the International Model for Policy Analysis of Agriculture Commodities and Trade (IMPACT) was developed as a "methodology for analyzing baseline and alternative scenarios for global food demand, supply, trade, income and population" (IFPRI, Robinson & Mason, et al., 2015). They have developed a series of equations that establishes a baseline of research that can then be utilized to inform the impact of carbon accounting on economic health, a prominent component of a politically feasible legislature. More explicitly, this research drives the advancement of sustainable, cost-effective, and efficient food chains that subsequently reduce emissions through transportation (IFPRI, Robinson & Mason, et al., 2015).

Finally, federal sustainable food action plans implemented by other countries globally are also expected to have influence over related political action within the United States. The majority of existing national strategies specifically highlight the right to adequate nutrition, with minimal focus on emissions reduction. However, the UK launched "Food 2030" based on the white paper "Food Matters" with the intention to "lead the world in sustainable food system strategies and policy implementation (Wilson & Brehm, 2010)." Through stakeholder interviews conducted within this research project, it was found that this action on the international level will have a resounding impact on corporate sustainability outside these countries. This is because multinational corporations (processors, wholesalers, and retailers) are likely to respond to regional mandates with policies that are company-wide, expanding emissions reduction strategies beyond borders (Wholesale 2 interview).

National Policy- United States

National Policy Landscape

Historically, the United States federal government has struggled to implement and enforce environmental policy proportional to its sizable impact on human-induced climate change. Due to the political controversy of climate agendas in the United States, there exists a lengthy rap sheet of failed policies associated with carbon reduction. Such controversies are discussed at length in the "Feasibility of a Federal Carbon Accounting Mandate" section of this report. Analyzing such failed policies in contrast to the recent passing of large-scale policies, such as the Inflation Reduction Act (IRA) and the Bipartisan Infrastructure Law, provides a guide for the development of successful federal carbon accounting policies. Such success is

defined both by the feasibility of adoption through the federal House, Senate, and Executive branch, as well as its scope of impact.

Recent successes such as the IRA and the Bipartisan Infrastructure Law express that broad-scope, climate-focused policies are possible when strategically constructed and supported. Both laws have origins stemming from the Green New Deal. This proposal was the US' first version of a national climate strategy and contained plans for building technology, infrastructure, and sociological and economic support for the advancement of domestic sustainable solutions. This policy failed in the House largely due to corporate and political backlash (Council for Foreign Relations, Chatzky & Siripurapu, 2021). The social movement behind broad-scale climate solutions, however, continued to grow and became a common platform for Democratic candidates in the 2020 presidential election following the Republican Trump Administration that broadly suppressed and ignored scientific research (Webb et al., 2022). Campaigning on a platform to "listen to the science" President Joe Biden committed to no longer question the threat of global warming and has subsequently adopted a highly progressive environmental agenda (Tollefson et al., 2022).

Although the Green New Deal, which began circulating political channels in the 2010s, gained notable political traction and public awareness, the bill also carried political and social controversy and was subsequently unable to pass through Congress (CFR, Chatzky & Siripurapu, 2021). As an alternative strategy, the Biden Administration passed the Bipartisan Infrastructure Law and the Inflation Reduction Act in 2021 and 2022 respectively. These two bills covered many of the initial goals of the Green New Deal with several adjustments. Originating as the Build Back Better Act, the Inflation Reduction Act was introduced to congress to simultaneously combat economic stressors caused by the Covid-19 pandemic and climate change ("Inflation Reduction Act Guidebook", 2022). Due to the highly politicized nature of the current US congress, this bill went through 172 revisions before its successful adoption in August 2022 (US Senate). The IRA represents the most aggressive legislation to combat the climate crisis in US history (US Environmental Protection Agency, 2022). In combination with the Bipartisan Infrastructure Law, the US is expected to reduce 2005 emissions by 40% by 2030 (World Resource Institute, 2022). The key drivers of emissions reduction are through the power, industry, buildings, transportation, and agriculture/forestry sectors. Totaling a $369 billion dollar investment, this legislation provides funding spanning from the development and adoption of clean energy infrastructure to the expansion of electric vehicles production and consumption, to investments in land production efficiency and conservation (World Resource Institute, 2022). While the later component of this bill has the most direct influence on carbon emissions within the US food system, due to the technological and systematic complexities of our current system, it can be assumed that many of the remaining investments will also have significant impacts on reducing the food system's net emissions.

Specifically, through the IRA, $20 billion will be specifically allocated over the next 4 years for GHG reduction through advanced agricultural practices, marking the first time in US history that Congress explicitly identified climate change mitigation as a goal for agricultural

funding (Environmental Defense Fund, Thomas, 2022). $300 million of such funding was specifically invested into the Greenhouse Gas Inventory and Assessment Program, which is intended to ensure conservation funds are increasingly effective, and efficiently distributed (Thomas, 2022). This program intends to establish data collection and reporting criteria for carbon, carbon dioxide, and methane emissions (US Department of Energy, 2022). This data collection and regulation is especially important for Life Cycle Assessment to reduce margins of error associated with various assessment methods. This subsequently serves as a notable foundation for large-scale carbon accounting initiatives. Previous drafts of the IRA attempted to allocate more than double the finalized amount, reflecting a closer estimate of the true cost of effectively calculating these measures for cross-sectional use (US Congress, "IRA Revisions"). However, if initial investments are deemed effective by the USDA as the regulating authority, appropriate funding allocations are politically feasible through the United States Farm Bill.

The Farm Bill is an omnibus legislation, meaning that it is giant by both scope and economic standards. This bill, originally introduced in the 1930s was designed to reduce economic threats to farmers following the Great Depression and Dust Bowl, by providing federal funding for subsidies and educational programs (Congressional Research service). However, since then, it has grown substantially to include everything from nutritional access to renewable energy production. This legislature plays a major role in how the US interacts with the global food system, as well as in countless market trends experienced in the US every day. Because this legislation is so extensive, it is edited, updated and processed through Congress approximately every 5-7 years (Congressional Research Service, 2018). The frequency that this bill passes through Congress, and its financial scope, represents a significant opportunity for the implementation of carbon reduction strategies, such as carbon accounting to become national policy. As it happens, 2023 is the next year in which the farm bill is reviewed, and with the current contention in US politics, there is more of a risk than ever that conservation and sustainability initiatives will be at risk for budgetary, and programmatic cuts. To prevent the defunding of these programs, the IRA extended funding for the primary conservation programs represented by the IRA through 2031(Thomas, 2022). Additionally, these programs were allocated historic increases in funding that are now tied to climate-focused "guardrails". These guardrails tie the program funds to projects that directly improve the environment or reduce harm through production practices (National Sustainable Agriculture Coalition, 2022). The Environmental Quality Incentives Program (EQUIP), the Conservation Reserve Program (CRP), the Agriculture and Conservation Easement Program (ACEP), and the Regional Conservation Partnership Program (RCPP) are all USDA programs that gained significant funding under the IRA.

EQUIP was allocated $8.5 billion (NSAC). A significant portion of these funds are allocated directly to the Conservation Innovation Grant within this program (NSAC). This grant provides financial resources and consulting for conservation plans utilizing cover crops, prescribed grazing, and efficient nutrient and resource management (NSAC). Furthermore, the program will prioritize funding applicants that "utilize diet and feed management to reduce

enteric methane emissions from ruminants," decreasing the number of incentives available for meat producers (NSAC). Notably, the IRA waived this program's previous requirement that 50% of funds be spent on livestock (NSAC). This change increases the availability of funds to other agricultural production efforts that are less costly to the environment. This is an especially surprising feat considering the lobbying power of Concentrated Animal Feeding Operations (CAFOS) (NSAC). Furthermore, this program includes innovation programs that have been historically underfunded. However, the IRA failed to extend payment limits for fund allocation to individual farmers. Payment limits for the allocation of government subsidies were originally set into place to prevent large shareholder farms from utilizing all resources, leaving little left for smaller farms (NSAC, 2022). It is feared that without this limitation, small farmers will continue to be at an economic disadvantage in the market, and that the gap for many may increase.

CRP was allocated $3.2 billion (NSAC). This program offers yearly rental payment for producers to remove sensitive land from production for carbon reserves and soil restoration (USDA). These funds can be applied to any project focusing on improving soil carbon, reducing nitrogen losses; or reduce, capture, avoid, or sequester carbon dioxide, methane or nitrous oxide emissions associated with agricultural production (USDA). Furthermore, the IRA explicitly extends support for organic and integrative agriculture, as well as providing funds to those transitioning into these practices (USDA). However, the IRA failed to extend payment limits within this program which, again, could have a substantial, negative impact on small farmers (NSAC). While the IRA extended the condition of setting funding set aside for disadvantaged, beginner, and ranch farmers the amounts have been historically criticized as not enough and were not expanded through this legislation.

ACEP protects croplands and ranching grasslands from non-agricultural development and restores/protects wetlands on agricultural land (USDA). The additional$1.4 billion in funding will continue these efforts as well as expand their scope of impact (USDA). Like many of the other programs, these funds are conditional, in that they may only be used for easements or interests in land that will most reduce, capture, avoid, or sequester carbon dioxide, methane, or nitrous oxide emissions associated with land eligible for the program.

Finally, $6.7 billion was allocated to RCPP (NSAC). This program promotes coordination of Natural Resource Conservation Service conservation activities with partners offering new insights about on-farm, watershed, and regional natural resource concerns (USDA). These Funds must be used to support the implementation of conservation projects that assist agricultural producers and nonindustrial private forestland owners in improving soil carbon, reducing nitrogen losses, reducing/capturing/avoiding/sequestering carbon dioxide, methane or N2O emissions associated with agricultural production (USDA).

Reaching beyond emissions reduction specifically related to the production sector, are federal policies that attempt to regulate carbon emissions across all sectors. More recent than carbon tax and cap and trade policy proposals, the Growing Climate Solutions Act of 2021 recently passed the Senate but died in the House. This policy attempted to authorize the United States Department of Agriculture to establish greenhouse gas technical assistance programs, and

a third-party certification program to reduce entry barriers to voluntary carbon credit markets for farmers, ranchers and forest owners (Bottemiller Evich & Monnay 2021). While this bill focused heavily on the production side of the food system, its advancement of emissions quantification strategies, and establishment of a small-scale carbon market greatly reflect the aspirations of an accounting mandate. Although this policy was supported by the American Farm Bureau Federation, the Environmental Defense Fund and the Nature Conservancy, three organizations with significant federal lobbying power, it was ultimately rejected by the House due to its focus on carbon offsets rather than explicit carbon reduction strategies (Bottemiller Evich & Monnay 2021). Limitations of carbon offsets, including natural sequestration caps and steep upfront investments, made this policy largely unpopular for House members advocating for small farmers and against large corporate emitters ("Oppose Carbon Offset Scams…", 2021). Future policies advocating for carbon markets and producer carbon accounting must withhold such policies and ensure that elements of environmental justice are thoughtfully integrated throughout the policy.

National Influential Actors

For large scale policies to gain enough political support to pass both the house and senate, they need to avoid becoming politicized, and be perceived by the broader electorate as feasible. Implementing policies within existing federal programs presents an opportunity to avoid such barriers to adoption.

The United States does not have a singular regulatory body associated with the food system. Instead, the implementation and enforcement of food policy spans across 20 different governmental agencies ("Urgent Call for a U.S. National Food Strategy, 2020) (Neberker, 2020). These federal departments include: the United States Department of Agriculture, Food and Drug Administration, Environmental Protection Agency, the Department of Interior, the Department of Commerce, the Department of Transportation, the Federal Trade Commission, the Department of Justice and the Department of Treasury. These agencies uphold responsibilities spanning across the purchasing of food for various government entities such as the military or public schools to regulating food related transportation or approving the use of ingredients in food for the general public, each agency maintains power in influencing the advancement of sustainability across the US food system.

The United States Department of Agriculture, Food and Drug Administration, and Environmental Protection Agency represent the largest economic influence, and public salience in the US food system. Therefore, policies from these departments are identified as prominent leverages in advancing carbon reduction strategies on a national scale. The USDA has played an active role in national emissions reduction in recent history, focusing heavily on those directly related to production. Such policies are expected to have reverberations across the entirety of the food system. The Agriculture Innovation agenda, passed in 2020, established a new standard for the USDA's role in emissions reduction while simultaneously ensuring the health and well-being of the US population. The USDA will henceforth "increase [food] production by 40%while

cutting the environmental footprint of US agriculture in half by 2050" (USDA). To reach this goal, the organization plans to reduce loss and waste by 50% by 2030, enhance carbon sinks through advancements of soil and forestry, and increase the production and efficiency of alternative fuel production from agricultural waste.

Opportunities for carbon accounting development exist within policies such as the Farm Bill, as previously discussed, and through programs such as Supplemental Nutrition Assistance Program (SNAP) and the Healthy Eating Index. SNAP provides food assistance to low-income families and individuals by subsidizing qualifying food products. While this program largely piggybacks off of surpluses, opportunities exist to instead subsidize food products that have reduced carbon footprints. Federal funding could then operate as an incentive for distributors to pressure sectors across the remainder of their food chain to calculate and ultimately reduce their associated emissions. Furthermore, the Healthy Eating index is a USDA program that collaborates with Health and Human Services to establish dietary guidelines as the basis of physician recommendations and standards for meal services, such as those within public schools, retirement homes, homeless shelters and refugee camps (USDA, "Healthy Eating Index"). This program aspires to find associations between diet and health outcomes. While the metrics that have been historically utilized have revolved around consumption patterns, there exists space to expand these metrics to those incorporating environmental health measures such as carbon accounting. Emissions reduction could more loosely be applied through this program through a reduction in ultra-processed foods provided and recommended. Such foods, on average, represent higher carbon footprints due to sourcing and processing emissions as transportation represents 6% of emissions and processing represents 4-15% (Joseph Poore & Thomas Memecek, 2018).

Producer focused regulation through agencies and programs such as those within the USDA have historically been the most prominent avenue for emissions regulation in the food system. However, advocacy against regulatory mandates by the agriculture industry is substantial, and very politically organized (Government 4). Therefore, a feasible carbon accounting mandate would need to both represent the needs of producers in the official legislation, as well as include legislative assurances that the economic burden would not solely fall on this sector (Government 4). Without such assurances, it is likely that legislation mandating carbon accounting would receive political backlash comparable to that faced by carbon taxation (Government 4).

These political barriers present the need for alternative strategies that target multiple sectors of the food system simultaneously. The Environmental Protection Agency (EPA) is the agency responsible for monitoring the health of the US population and their environment. The relationship between this agency and the food system primarily exists within its regulatory power across other agencies and corporations. The Clean Air Act (EPA, "Clean Air Act") defines the EPA's responsibilities for protecting and improving US air quality. Established in 1970, and revised in 1977 and 1990 (EPA), this policy sets the national air quality standards for 6 "criteria pollutants": ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead. Under this law,

all states must maintain air quality standards, and control emissions drifting across state lines, and all emerging industrial plants must adopt "best available technology" with less pressure on older plants. While separate federal laws explicitly calling for the control or reduction of greenhouse gasses, including carbon, have largely failed, extending the authority of the Clean Air act by amending the criteria pollutants to include carbon presents substantial opportunity. Four primary options for emission reduction efforts exist through the CAA (Monast & Profeta, 2010): regulating GHGs as criteria pollutants, regulating sources of GHGs under the New Source Performance Standards program, entering into a bilateral agreement to control international air pollution, or regulating GHGs to protect the stratosphere. Regulating sources of GHGs under the New Source Performance Standards program is the most cost and time effective approach. This program regulates emissions directly at the source, setting an emissions cap on new and modified stationary sources. Additionally, this approach allows a tailored regulatory approach and market-based mechanisms through which emissions can be both monitored and reduced. However, in 2021 the Supreme Court ruled that the EPA was not permitted to set emissions caps, nor regulate emission standards on the state level. This diverts responsibility to state legislation and represents a barrier to broad emissions control on the national level (US Supreme Court, 2021).

The Food and Drug Administration primarily regulates how food is produced and packaged within the US. While this department does not have regulatory power over emissions reduction, advancements in labeling practices present opportunities to translate ecological targets from the producer to the consumer. Food labels first appeared in 1994, and were revised in 2016 and 2020 to contain additional information deemed necessary for informed food purchasing (National Library of Medicine "Front-of-Package Nutrition Rating Systems…"). These changes enhanced clarity through standardized formatting, and transparency by requiring complex food products to report statistics on their caloric and fat content (National Library of Medicine). Mandating food distributors to display quantitative information about the carbon footprint of individual food products would allow consumers to utilize their buying power to shift the food system toward low carbon foods.

Supported by the literature and stakeholder interviews, all aforementioned strategies for advancing the salience of carbon accounting within the US food system if effectively implemented, adopted and regulated have potential to reduce net US emissions. The success of both adoption and scope of impact are reliant on how such policies are implemented. For instance, due to the variety and quantity of food labels emerging in the global and US market, ambiguity in the information being presented is substantial. Mandating carbon labeling would offset the responsibility to understand and account for food related emissions from the supply chain, and onto consumers through purchasing power. However, the success of this policy is highly dependent on successful standardization of carbon reporting, and an easily comprehensible label for consumers (Consumer Expert 3) (Data Researcher 2). This is to prevent corporations from skewing their reported data for financial gain and ensure that consumers are capable of making informed decisions without requiring substantial background knowledge. To maximize the impact of carbon labeling, and the opportunity for legislative success, Advocacy

Org 1, also noted that companies within the food supply chain should work cohesively to achieve carbon neutrality, utilizing both system influences and market power to initiate change (Advocacy Org 1). Compared to other labeling systems, carbon neutrality is a single measure with a more precisely defined goal. A carbon neutral label would communicate to consumers that the net emissions utilized throughout the food chain for the creation and distribution of a food product, were directly counterbalanced through investments in sequestration or energy reform. This is an alternative strategy that has potential to achieve similar goals of reporting and emissions reduction. However, because this metric is more ambiguous (i.e. what are the offsets) there remains more opportunity for this labeling system to be utilized for capital gain, instead of actually representing sustainability measures.

Furthermore, as discovered through stakeholder interviews, the most effective policy would utilize collaboration across groups and incorporate equity (Government 4). While extremely difficult to distill and accommodate all needs of all sectors of such a complex system, engaging as many prominent actors in the drafting process will reduce political backlash, increasing feasibility of adoption into law (Government 4).

State Policy

State Policy Landscape

While most of the regulation of food exists at the federal level, state governments do have the authority to regulate food businesses, processing, and retail. Any state policies must meet or exceed the federal regulations ("Organization of U.S. Government", 2017). While they are small governments in comparison to the federal government, states offer a unique opportunity for decreasing food-related emissions given large jurisdictions since state policies collectively can decrease national emissions. This means that a carbon quantification mandate at the state level can be easier to obtain than one at the federal level and still have a significant impact. Policies in California, for example, have forced companies operating inside the state into changing conditions for the company at a national scale. One example of this is Proposition 65, or the Safe Drinking Water and Toxic Enforcement Act of 1986. This bill requires companies to include a warning label on products that contain a substance known to cause cancer. With the uptick of e-commerce, more companies have “put the labels on everything - even on items that aren’t necessarily bound for California " (Suithivarakom, 2020, para. 9) . The purpose of this bill was to give consumers information about ingredients in a product and then let them make their own choices. A carbon label on food would have the same purpose (Suithivarakom, 2020).

Prior to considering food-emission related policies, states must first set goals for total emission reduction. Only 25 states and the District of Columbia have greenhouse gas emissions targets ("U.S. State Greenhouse Gas Emissions Targets", 2022). Most of these state targets have a short-term goal and a long-term goal. Connecticut, for example, passed legislation in 2018 to reduce emissions 45% by 2030 and 80% by 2050; the other 25 locations have very similar goals. The pathway to address the emissions, however, rarely includes the food system. Many of the policies coming out of these states in order to reach these goals are focused on energy, transportation, carbon pricing (cap and trade), and carbon taxing ("State Climate Policy Maps", 2021). Even some of the most progressive states do not have policies

addressing food and agriculture as a main emissions source ("California Climate Policy Dashboard", 2022). The California Air Resources Board, the government agency in charge of air pollution, measured that agriculture is the state's fifth largest source of carbon emission equivalents, with the majority of those coming from livestock. The state responded to this in the form of program funding for anaerobic digesters, manure management, healthy soils, and water enhancement but these fail to address emissions at the source ("Assessing California's Climate Policies - Agriculture", 2021) . Other states, such as Louisiana, may not have explicit policies for agriculture but may reference its impacts in an overarching goal to "regulate methane emissions" or something similar ("Louisiana Climate Action Plan", 2022).

Some of these states with GHG targets, in fact, focus more on the impact climate change will have on food production rather than the opposite. Wisconsin and Vermont are two states that have published concerns over the future of food production in the state due to the changing climate. Wisconsin has extensive plans for climate change mitigation. Carbon emissions in each industry in the state have decreased from 2005 - 2017 except for agriculture and industrial processes. Agriculture is the sector with the largest increase on an "absolute emissions" basis ("Governor's Task Force on Climate Change Report", 2020, p. 16). The state's response to this climb is to incentivize the decrease in emissions on each farm, putting the onus on farmers and ranchers.

> "Although agriculture currently is a net source of emissions, farms and ranches hold great potential to generate negative emissions from increased carbon sequestration and reduce emissions from operations through low-cost strategies, in addition to providing other critical societal benefits such as food, habitat, and economic growth." ("Governor's Task Force on Climate Change Report", 2020, pg 50)

In a Climate Change Adaptation White Paper Series, Vermont's Agency of Natural Resources discusses the possibility of seasonal shift due to climate change and how this will impact the "culture and economy" of agriculture ("The Potential Impacts of Climate Change on Agriculture in Vermont", 2010, pg 1). Dunnington (2010) discusses how large-scale plant farming in Vermont can aid in their mitigation efforts, but also how "methane recovery targets" are helping. These methane reductions include methane generators on dairy farms, one of the main sources of methane in the state ("The Potential Impacts of Climate Change on Agriculture in Vermont", 2010).

The carbon quantification mandate would be one of the first of its kind at the state level. Without support, the policy would likely lose traction due to heavy investments (and prioritization) in mitigating carbon emissions in other sectors (energy, transportation) and the lack of a policy precedent. Despite the lack of literature and policies addressing the food system specifically, there are a handful of states that are dedicated to reducing GHG emissions.

State Influential Actors

Due to the lack of federal policy directly addressing climate change, state policies and reduction targets are leading the way (Holland et al., 2020). The United States Climate Alliance was created by governors in 2017 in order to work together and "advance climate solutions" according to the Paris Climate Agreement (Holland et al., 2020). These states agreed on four main commitments: 1. Reduce net GHG emissions and achieve net-zero emissions by 2050; 2. Support and enact policy to reduce GHG emissions, build resilience, and promote clean energy; 3. Put an emphasis on environmental justice and high-quality jobs; 4. Track and report this progress to the world, specifically when countries come

together for the Paris Agreement ("Alliance Principles", n.d.). These states are paving the way for future legislation, both at the federal level and at the state level. The country's largest agricultural producers are California, Illinois, Indiana, Iowa, Kansas, Minnesota, Nebraska, North Carolina, Texas, and Wisconsin. Half of these states are in the Climate Alliance and include California, Illinois, Minnesota, North Carolina, and Wisconsin. The Climate Alliance is a major leverage point for the carbon quantification mandate because these five states already have missions in place to mitigate climate change and also have large food production economies. These states present an opportunity for modeling a balance between the likelihood of getting the mandate passed and influence of the mandate. Implementing policies in other states, however, may have a larger impact.

If a carbon quantification mandate were passed at the state level, it would mean that all food companies based within that state would be required to calculate their products' carbon emissions. The difficulty with this proposal is that the companies have the opportunity to leave a state to avoid this restriction. For a policy to be influential at the state level, it would need to be a reporting mandate. This means that companies would need to report the carbon to consumers within that state, very similar to California's Prop 65. Another option is to require food producers, such as farmers and ranchers, to record their carbon emissions. This is not ideal because as this is the beginning of the product's life cycle, it can only address carbon emissions from production. For instance, if applied to the meat industry, it would only track methane from raising the livestock and would not include packaging, storage and transportation.

There are other organizations that work to promote policy for climate change at the state level. These entities may be useful in lobbying for and passing a carbon quantification mandate. The Good Food Institute (GFI) is an NGO working to end animal agriculture through alternative proteins. The meat and dairy industries are main sources of carbon emissions, so GFI lobbies at both the state and federal levels in order to pass legislation, secure funding, and petition for its end. GFI's lobbyists were influential in many court cases. In one specific case in Arkansas regarding label censorship, they helped the Tofurkey company secure the right to label their products as meat ("An Overview of Food Label Censorship", 2022). This is just one example of an organization that can aid in the passing of state legislation. Another example of an organization working to promote food climate policy is the Center for Food Safety (CFS). This non-profit has, among other goals, the mission of working in courtrooms to ensure that consumers are informed about harmful chemicals or pesticides exposure through their food. In one victory, CFS "wrote, lobbied, and passed a first-of-its-kind bill" that banned chlorpyrifos in Hawaii ("Victories and Accomplishments", 2023, para. 10). This type of legal advocacy could be very helpful in the lobbying and passing of a carbon quantification mandate. The Good Food Institute and the Center for Food Safety are examples of many possible institutions that are set up to assist in addressing carbon quantification goals.

Local/Municipal Policy

Local/Municipal Policy Landscape

The organization C40 is an association of mayors from across the globe who have pledged to take meaningful action in reducing emissions to bring their cities in line with the goals of the Paris Agreement (*About C40,* n.d.). As recognition grows that addressing emissions

from the agricultural sector is critical to meeting global targets, this group of municipalities provides a possible point of leverage with this group (Clark et al., 2020). However, most local plans for tackling climate change are planning documents and do not contain actionable steps for implementation or accountability metrics and few consider dietary choices or other Scope 3 emissions (Harris, 2022). Generally, municipalities do not have the jurisdiction to enact rules or regulations regarding food provisioning practices. In interviews, Government 2 noted that the municipality they are the mayor of has a land conservation fund that encourages farming near the city, but they said that was the extent of influence the municipality could have on what sort of food production happened in its proximity. While this limits the potential of policy action on the municipal level, there are still opportunities for municipalities to contribute to emissions reduction efforts within the US food system.

Local/Municipal Influential Actors

Smaller municipal governments do not have the same pressure from lobbyists that the federal government does. There are still interests from private actors but there is a closer link to constituents who can generate and act on political will. One example of such impactful local policies is Multnomah County, Oregon, home to Portland, which has a reputation as one of the most progressive cities in the nation. Multnomah County has a new income tax as of 2021 that funds tuition free preschool for all three- and four-year-old's ("Preschool for all", n.d.). Universal preschool, much like reducing greenhouse gasses, is a priority for many people in the United States, yet the federal government has been unable to make any progress in addressing it. Multnomah County provides an example by funding early childhood education that can be extrapolated to other major issues. Similarly, Boulder County, Colorado has an excise tax on sugary drinks that funds food access programs on the local level (Public Health, n.d.). These two programs are examples of how local municipalities can have significant impact by targeted use of financial resources without putting mandates or restrictions on areas beyond their scope of power.

Enabling initiatives are a strategy in which a local government agency creates an opt-in program that local business and organizations can join, receiving a certification or designation that can improve their reputation and be leveraged in marketing (Romero-Lankao, 2012). They are highly feasible because of their low implementation costs, and can be very effective because they are seen as an opportunity rather than a requirement, cueing positive perceptions among participants. Local governments can also leverage their influence to bring together coalitions of private and public partners that share the common goal of reducing emissions (Hughes, 2017). In this way, local governments can be places of innovation and collaboration and the ones that have the political will and resources to act on climate issues can serve as leaders and modelers for subsequent initiatives (Bansard et al., 2017). A 2017 report from SUNY Buffalo catalogs programs in Portland, OR; Oakland, CA; New York City; Minneapolis, MN; and Kansas City, MO that are actively improving local food systems (Neuner et al., 2011). Priorities in the

programs differ, and generally focus on food security rather than sustainability, but provide templates for local initiatives that have sustainability as a unifying goal.

Lobbies

Lobbyists are dedicated persons who legally influence government policy and action in their interest whether it's based on scientific fact (Nestle, 1993). From one view, lobbying is needed in order to inform Congress about issues, stimulate public debate, and encourage public participation on issues. However, food lobbies consisting of corporate groups and businesses tend to have substantial resources at their disposal in order to influence federal decisions as opposed to individuals and advocacy groups (Nestle, 1993). Given such expansive resources, corporate lobbies are unequal in influence meaning that groups with the most resources get support for their policy recommendations. For instance, the National Cattlemen's Beef Association, American Soybean Association, National Broiler Council, National Fisheries Institute, American Meat Institute, Cargill, ConAgra, Corn Refiners Association, National Frozen Food Associates, National Corn Growers Association, and United Egg Producers are some of the biggest food lobbies in the United States with considerable power and influence over food system legislation (Nestle, 1993).

Some advocacy groups argue that corporate lobbies (those who are advocating for *and* against carbon quantification regulations) are distracting from the true source of emissions in the food system (Advocacy Organization 2). Advocacy groups that fall under this ideology are interested in advocating for policies that directly cut emissions such as banning factory farms, diversifying small and regional food systems, and de-consolidating the food system so that there are no monopolies that control food policy (Advocacy Organization 2 and 3). Calculating emissions takes an enormous amount of time and every dollar that goes into calculating emissions is another dollar not going into programs that actually reduce emissions (Advocacy Organization 2 and Government 3). The Advocacy Organization 2 interviewee argues that carbon quantification leads to the creation of a carbon market which then ignores the short- and long-term carbon cycle and sustainability. Other advocacy groups support the idea of creating 'climate smart' markets, requiring communicating the supply chain to eventual customers as well as focus on innovation and R&D (Advocacy Organization 3).

Trade associations have a similar amount of power since they are highly competitive and highly centralized (Processor 3). As food companies grow and own more of the supply chain, they increase their revenue and their lobbying potential. Vertical integration allows a single company to be involved in the same products. For instance, Smithfield Food is responsible for the breeding, production, slaughter, processing, and marketing of hogs and pork products (Johns Hopkins Center for a Livable Future, 2023). This one company has tremendous power over the market share. Again, this undermines and undercuts the work that advocacy organizations do to reduce emissions as power and influence over food system policies are in the hands of a few lobbies and trade associations.

Advocacy Organizations

There are many entry points for food system related advocacy organizations/NGOs to make an impact on reducing emissions. An example in Europe that can be replicated in the US is the EAT Forum. The forum created a Food and Land Use Coalition and the Food Trails program in order to bring together a consortium of 19 partners across Europe that are dedicated to co-creating urban food policy that is sustainable and in line with the sustainable development goals and national science-based targets (Food and Land Coalition). Other entry points include advocacy organizations working to dismantle factory farms which use fossil fuels (i.e. Food and Water Watch), helping with the planting of perennial crops (i.e. The Land Institute), and reducing chemical input and food waste (i.e. National Resource Defense Council) (Food and Water Watch, 2021; The Land Institute, 2022; NRDC, 2022).

Advocacy organizations play an important role in aiding corporate level actors with information (Advocacy Organization 1). For instance, advocacy organizations can conduct LCA for corporate GHG inventory and work to get these corporate actors strategizing ways of reaching net zero targets and commitments (Advocacy Organization 1). Alternatively, carbon neutrality is often easier to message to customers than a carbon quantification label and carbon budget, thus many advocacy organizations focus on this type of strategy (Advocacy Organization 1). The problem or challenge in this method is that the few advocacy organizations that do calculate LCA have the requisite staff or resources to regularly update the LCA throughout the year. Even with such resources available, there are data barriers that stand in the way of calculating an accurate carbon equivalent. In the current era of supply chain disruptions, traceability and transparency have been sacrificed for delivery (Advocacy Organization 1 and Consumer Expert 4). Furthermore, the methodology and data source itself can vary across advocacy organizations that conduct LCAs which makes it difficult for consistent and easily interpreted carbon dioxide equivalent (Advocacy Organization 1). In addition, information on the production of processed foods, seasonality, transportation, etc. is constantly changing, which potentially increases uncertainty and inaccuracy across advocacy organizations conducting LCAs (Advocacy Organization 1).

Current State of Carbon Accounting

Producers

Producers, particularly meat producers, have significant potential to reduce GHG emissions on-site with changes in management. Cusack et al. (2021) found that carbon sequestration management on grazed land can reduce net GHG emissions by 46% per unit of beef. Carbon sequestration, however, mostly applies to cattle farmers using rotational grazing (Producer 1). As a response to growing concerns of climate impacts, The National Cattlemen's Beef Association created a monetary incentive for farmers to reduce emissions. Ranchers can do this through rotational grazing, cover cropping, integrated ranch management, beneficial fire management, forest restoration, riparian area management, or avoiding conversion of grasslands to tillable farming in order to trap excess carbon in the soil (Wright & Harris, 2021).

Other large scale non-cattle producers, such as Dole, have turned their attention to reducing food waste in order to reduce carbon emissions. For instance, Dole launched a program with Musa Fabric that upcycles banana peels by turning them into fabric. Dole also launched a program that will digitize fruit quality control checks using cloud based technology (Dole, 2020). Another way producers can reduce emissions is through the use of precision agriculture. Precision agriculture is an approach that tracks fertilizer loss and informs producers on fertilizer efficiency (Environmental Defense Fund, n.d.). Land O'Lake SUSTAIN Platform is an online software designed to make farming more efficient and environmentally friendly by providing sustainability recommendations to the farmer based on Land O'Lakes' analysis of farm inputs and outputs (lLand O'Lakes, n.d.). This gives farmers the knowledge and tools to understand their environmental impact acre by acre. However, this is most commonly used by large scale producers, and not by small scale producers because of barriers discussed in the challenges section of this report.

Arguably the most attractive way for any producer to reduce emissions is through on-farm energy production. For instance, agricultural renewable natural gas (RNG) production is one way this is being implemented. For meat producers the EPA listed 96 manure-based anaerobic digester systems producing RNG with 34 new projects under construction in March 2021 (Kusowski, 2022). Anaerobic digester systems have the ability to lower emissions but producers know they must do more to reduce greenhouse gas emissions as social norms and policies continue to push for the adoption of other sustainability practices (Kusowski, 2022). Other ways of reducing on-farm energy production include the use of geothermal, solar thermal, wind turbines, solar panels, and rechargeable batteries (British Columbia Agriculture Service, 2023). One of the largest farms in the United States is owned by the Resnick Family and totals 190,000 acres. The Resnick Family started the Halos project, the largest single-site solar rooftop installation owned by a private company (i.e. Wonderful Pistachios and Almonds). The company Wonderful has plans to be 100% renewable by 2025 (Wonderful Company, 2022). They have also converted all of their almond and pistachio land to no-till systems which further reduces the

environmental impact. Another 190,000 acre farm in the United States is owned by the Offutt Family primarily growing potatoes in Minnesota. The farm is next to Xcel Energy Solar development project and has invested 1500 acres of farm land to be converted to hold solar panels (R.D. Offutt Farms, 2022). Low emissions tractors in the fleet, converting diesel-generated irrigators to electric irrigators, storage facilities having LED lighting, and cutting horsepower requirements by 50% are all ways that R.D. Offutt farms use less energy (R.D. Offutt Farms, 2022).

Other approaches for producers to reduce carbon emissions can be crop dependent. For example, the Fanjul Family farm comprises a total 152,000 acres of farmland in Florida and is responsible for growing most of the country's sugar cane. Sustainability efforts in the production of sugar cane include introducing barn owls throughout the field to reduce crop loss to rats and the use of high-tech GPS guided planting tractors for accuracy and efficiency during planting otherwise known as precision agriculture (Florida Crystals, 2023). Finally, partnering with universities and other research institutions to understand on-farm best practices are ways farmers can learn about how to implement and manage such energy reduction processes and resources (Florida Crystals, 2023).

The primary barriers for adopting these carbon reduction strategies include cost, tradition, the shift in agricultural production and demographics, government regulation, and environmental factors. For small scale producers, it is increasingly difficult to pay for the cost of simply growing food let alone having to pay for the implementation of carbon reduction strategies, especially since farmers allocate a tremendous amount of time and resources to comply with regulations and standards without compensation (Producer 3 and Government 1). To demonstrate how costly operating a farm is: for every dollar that was spent on food in 2020 only 16 cents went back to the farm; in 1975, 40 cents went back into the farm (University of Michigan Center for Sustainable Food System, 2023). Clearly, there is a mismatch when it comes to scale and production when large scale producers (i.e. large scale family farms and globalized industrial farms) make up 5% of total farms in the United States but almost 60% of production in terms of dollar amount; on the other hand, small scale producers make up almost 90% of all farms in the United States but only 20.4% of production in terms of dollar amount (University of Michigan Center for Sustainable Food System, 2023).

According to the USDA, since 1900, the number of farms in the United States has fallen by more than 60% while the size of each farm continues to increase (USDA< 2005). From 1992-2012, total crop land decreased approximately 68 million acres (University of Michigan Center for Sustainable Food System, 2023). The reasoning behind this is that there is a shift of production and changing demographics. As early as the 1950s, large-scale production was possible because of the mechanization of agriculture. Labor costs decreased and production increased making it possible for large scale corporations to exist as monopolies. With this power they were able to influence what producers can grow (Johns Hopkins Center for a Livable Future, 2022 and Schepers, 2010). One way this plays out is at the level of agricultural research and development. Industrial agriculture, with its agricultural lobbies, influences land grant

institutions and services making it harder for more sustainability-motivated producers to access resources (Producer 1). Additionally, the increased size of farms requires larger equipment. Equipment is being made for large scale production and not small-scale production (Producer 1). Equipment cost and access to funding are huge barriers to small scale producers (Producer 1). In addition, some producers do not have the carbon emissions data for products to then give to distributors and other actors that can influence the system in order to reduce emissions (Data 2).

Finally, demographic and culture play a role in how feasible it is for producers to reduce carbon emissions. The farmer population age is increasing and there are not many young people willing to take on the role of the farmer. Given that the average age of farmers in the United States is 57.5 years, tradition plays a role in what sustainability measures will be adopted (USDA, 2019). Older generations tend to stick with traditional practices that are not necessarily always sustainable.

Producers shared that most producers, typically small-scale producers, have limited authority to make significant changes in the production because of government regulations. While some of these regulations provide guidance, others provide financial assistance on which farmers rely. It is therefore critical that government assistance is provided to producers during the transition to more sustainable practices (Government 3, Producer 1, and Producer 2). Without government assistance, a lot of farmers would go out of business (Data 1).

Other environmental factors influence whether producers have the ability, financial or otherwise, to implement carbon reduction strategies. These environmental factors include drought, land use regulations, wildfires, and access to renewable energy infrastructure. Addressing environmental impacts can pose significant barriers for both large and small scale producers but especially for small scale producers that typically don’t have much access to resources.

While consumers tend to view producers as having a lot of power to change the system, they do not (Consumer Expert 1). Producers are mainly influenced by other sectors which makes producers a weak leverage point for emissions reductions. Distributors and processors have the most influence on producers which makes producers sit in the middle of these powerful sectors (Consumer Research 1). For example, wholesalers can exert pressure on suppliers, and hold them accountable, for animal welfare standards (Wholesaler 3). This suggests that other sectors such as wholesalers, distributors, and processors etc. can influence producers much more than producers have power to change producers.

Processors

Processors refer to companies that use processing to transform raw ingredients into “recognized, regularly consumed” food products ("What is the Food Processing Industry?" n.d., para. 2). There are many methods of processing including cooking, smoking, freezing, pasteurizing, and adding chemicals/preservatives ("What is the Food Processing Industry?" n.d.). Processing contributes to at least four different types of air emissions: methane, nitrous oxide, carbon dioxide, and hydrofluorocarbons (Tubiello, 2022; Hitaj, 2019). These make up 19% of

the total emissions from food (“US Food System Factsheet,” 2021). Due to the consolidation of the food industry, many processing companies are cooperatives, or conglomerates.

According to “Food Processing” - a magazine focused on providing the food processing industry with key information such as profits, product development, supply chain, and mergers - the top three food processing companies in the United States in 2022 were PepsiCo., Tyson Foods, and JBS USA ("Food Processing's Top 100," 2022; "About Us - Food Processing," n.d.). JBS has a commitment to sustainability where they mention multiple avenues of decreasing emissions: reduce packaging, eliminate waste, turn fat into renewable jet fuel, and use methane gas from wastewater treatment to replace dependence on fossil fuels ("Sustainability Story," 2022). According to their stated emissions reduction goals, however, the company has only committed to reducing scope 1 and 2 emissions by 30% in 2030. Based on this goal, one can assume that the company does not calculate nor report its scope 3 emissions. While they have reduced their scope 1 and 2 emissions by 8% since 2019, they do not report their total carbon emissions. Given that they are the largest producer of meat in the world, their emissions are most likely very high ("Sustainability Report," 2021); Foley, n.d.). PepsiCo and Tyson Foods have similar approaches to sustainability, all indicating that they calculate their carbon emissions, have a reduction goal, or even a net zero emissions goal (“Sustainability Action Center," 2023;"Tyson Foods | Sustainability," n.d.).

It is important to recognize that there is a distinction of power, influence, leverage points, and generally sustainability efforts between large and small processors. Based on both research and interview analysis, most large processing companies are calculating their carbon emissions and likewise they have stated sustainability plans. This is not always true for smaller processing companies. One smaller processor spoke about calculating scope 2 emissions on products, saying they have only completed LCAs every few years, and that these LCA’s were not used to reduce the emissions of the company (Processor 2). As reported by several interviewees, that even with resources available to pay for the LCA, a GHG metric alone tells a very incomplete story. Other factors that cannot be calculated, such as deforestation, justice and equity, biodiversity, etc. are typically not considered. This small processing company was more focused on other environmentally focused goals, ones that aligned with the ingredients of their products and water sourcing (Processor 2). Another processing company that was interviewed, which was substantially bigger, has company values related to reducing carbon emissions and using carbon quantification to do that. The interviewee believes that companies like theirs should be responsible for paving the way and leading by example (Processor 2).

Small processing companies may not have the ability to reduce emissions as much as the larger companies. The three large corporations mentioned above own many of the stages of production (vertically integrated) whereas other processing companies may only control the factories that do the processing. Considering the limitations of smaller processors, the main areas for reduction may lay in energy and packaging. Foremost Farms, a small processing company, mentions sustainability only when highlighting new packaging, despite being a dairy processor, which is an industry known for high emissions ("Tailored Innovations from Seasoned Pros,"

2023). Another small processing company, B & G Foods, has a page on their website dedicated to corporate responsibility and mentions zero waste, energy reduction, and reforestation as the main ways to reduce emissions ("Corporate Social Responsibility," 2022). Leverage points within a company can also include changing procurement guidelines, which is more applicable to larger processing companies due to resources.

Large processors have the potential to reduce emissions that occur upstream of the supply chain (i.e. scope 3 emissions) through sourcing and contract stipulations. Carbon reduction strategies are often viewed as linear but this is not the case. Successful and effective strategies are multi-leveled and non-linear, and some processors have already adopted such tactics (Touboulic et al., 2018). Tidy et al. (2016) exemplifies this multi-leveled approach using Supplier Engagement Programs (SEPs) as a way to reduce emissions in a retailer's procurement networks. SEPs help shape relationships between focal companies (e.g. retailers and processors) and other actors in the supply chain such as distributors, other processors, and primary producers. The focal companies try to influence behavior of upstream companies through collaboration and cooperation towards a goal (i.e. emissions reduction). The result is a more sustainable supply chain because the companies are working towards that common mission. Another example of corporate cooperation is the Carbon Disclosure Project (CDP). It is a "not-for-profit charity that runs the global disclosure system for investors, companies, cities, states, and regions to manage their environmental impacts" and so it helps large processing companies calculate, understand, and disclose their carbon emissions using Science Based Targets (SBTs) ("Carbon Disclosure Project Homepage," n.d., para. 1; Hart et al. 2020).

SBTs are goals with set plans to reduce emissions that are in line with the Paris Climate Agreement science ("What are 'science based targets?" n.d.). Recently, companies have started to see sustainability as a topic under corporate social responsibility due to pressures from consumers. This could be a primary leverage point in getting companies to not only quantify carbon but release it to consumers, which is what the CDP encourages companies to do. By releasing the information to the public, the company may feel inclined to decrease their carbon footprint in order to solicit customers. According to an article published by Margaret Malochleb in the Institute of Food Technologists titled "Sustainability: How Food Companies Are Turning Over a New Leaf," consumers are calling for transparency from companies, and the companies that have obliged see higher revenue and growth (Malochleb, 2018). This seems to be a significant reason for why processing companies make sustainability a priority. This could be a primary leverage point in getting companies to not only quantify carbon but release it to consumers. If consumers are worried about transparency, then being able to see carbon emissions of the company, or even carbon emissions of food products, would be full transparency for the consumer. Without a case for increased revenue, however, reporting carbon emissions might not be realistic

One processor mentioned that, despite being the head of the sustainability team, in order for a company goal such as emissions reduction to be heard by executives, there needs to be a strong business case (Processor 2). Another sustainability director spoke about this as well, and

they were at a company known for sustainability (Processor 4). The interviewee mentioned that it was near impossible to deviate from the company mission for the sake of sustainability (Processor 4). They also spoke about how the best way to make change in the company was to prove there would be a Return on Investment (ROI) (Processor 4). According to IBM, some reasons why companies would commit to sustainability policies are employee recruitment, a markup on goods, investor demands, government intervention, and future resiliency ("Sustainability in Business," n.d.). Carbon quantification on products can be used in marketing campaigns to align with consumer values. One processor spoke of this and how full LCA's are only conducted on products that can be used in these types of marketing efforts. They use "estimation tools" on the products that will not be put through a full LCA (Processor 1).

Processing companies, especially the larger ones, have the ability to reduce all emissions (scope 1,2, and 3) through their processing techniques and procurement. Fortunately, they do seem to be calculating their emissions. Of the 6 processors spoken to, all spoke about calculating scopes 1 and 2 emissions. All but one spoke about scope 3 emissions. Most also noted that they calculate product-level emissions on some of their products, but not all due to limited labor, resources and data capacities.

Wholesale

Wholesalers are a form of food distributors that sell food in bulk to retailers, food service locations, governments, or other wholesalers ("Retailing & Wholesaling", n.d.). The opportunities for these companies to reduce emissions are similar to the leverage points for processors. Wholesalers can most effectively reduce emissions through energy reductions and packaging. Since distributors are a middleman, most of their emissions are scope 3 and beyond their control. Wholesaler 3 cited that over 90% of their emissions are scope 3. Similar to processors, in order to change scope 3 emissions procurement and supply chain choices would need to change. Wholesaler 3 talked about this:

> "We're the first food distributor to take a science-based target for emission reductions and put it in our financial reporting. We are prioritizing [it] but learning how to communicate that to our suppliers and how to hold them accountable is still in development. One nice thing is that as a larger company, we work with a lot of larger suppliers, and they are also starting to look at their emissions."

Also similar to processors, all three of the wholesalers interviewed said that they are calculating companywide emissions and some product level emissions. For product level emissions, Wholesaler 1 mentioned that in order to calculate associated carbon emissions, they require data from their suppliers and the need to trust that it is accurate. While distributors do add to overall carbon emissions, they are not a leverage point for reduction due to their limited influence on the greater system. As mentioned above, their main influence is with their suppliers. Wholesalers have two other leverage points, however, that are unique to their sector.

Some wholesalers, such as Costco, can sell directly to consumers rather than sell to restaurants or other retailers. This can reduce emissions by cutting out a step in the supply chain, as they circumvent transportation, storage and packaging related emissions. Wholesalers can also reduce emissions by reducing food waste. According to the USDA, between 30 and 40% of the nation's food supply is never eaten ("Food Waste FAQs," n.d.). Distributors, i.e wholesalers, have the opportunity to prevent the waste

from going to landfills (Pappas, 2022). There are three ways that wholesalers can do this: donate to local nonprofits, donate to farms so the discard can be animal food, or compost the food waste (Pappas, 2022). Prior to the retail stage, food is discarded due to contamination by insects, rodents, birds, molds, or bacteria. At the retail stage it is generally due to equipment issues, over-ordering, or produce blemishes ("Food Waste FAQs," 2022). The latter can be avoided or mitigated using the same methods as mentioned previously. Reducing the amount of "wasted" food could cause a direct decrease in emissions by avoiding methane secretion in landfills. Wholesaler #3 supports this reduction strategy; their company has committed to reducing food waste by 90% by 2025 (Wholesaler 3). The leverage points for emissions reductions within wholesalers and distributors are easily attainable but may not have the biggest impact due to most of their emissions being scope 3.

Retail

Retailers source food products directly from producers or processors, then market these products to public consumers (HPLE, 2017). Retailers range in size and structure from local farm stands to large grocery stores and restaurants, but all represent the exchange of money for consumable goods and serve as the point between the rest of the supply chain and the consumer. The landscape of retail in the US food system has changed significantly over the last 50 years as large grocers have emerged, mirroring consolidation in other sectors and becoming integrated with sectors through mergers (HLPE, 2017; Hendrickson et al, 2018). Retail expansion is correlated with an increase in highly processed foods available for purchase and consumption, and the increase in processing also complicates the food supply chain and interconnection of sectors (Monteiro, 2017). As of 2012, American consumers spend more money on food prepared away from home than on raw ingredients for home preparation, amplifying the role of take away prepared foods and restaurants in the US food system (Elitzak & Okrent, 2018). Retailers, if motivated to engage in sustainability efforts, can have a significant influence on consumer knowledge and perception about sustainability (Lehner, 2015).

Procurement is also a link in the retail chain, because it is the process that determines what products retailers present to consumers. The UN report on *Just Rural Transitions* (2021) highlights the potential of procurement policies as leverage points in working toward a sustainable food system. The UN provides a sample "Climate-Friendly Procurement Policy" that can be used to drive purchases toward selections that center environmental priorities. This is an avenue that can achieve similar results to regulation but operates in a less direct fashion. In the United States, the Executive Branch and government departments can enact procurement policies without relying on legislation passing Congress. The Biden administration began to lay the groundwork for a procurement policy in 2021 and the EPA has procurement guides that prioritize sustainable and healthy food (sustainability.gov; epa.gov). The Good Food Procurement Policy created change in the supply chain through the LA County school district by creating five criteria to evaluate all purchases (UCS, 2018). Procurement policies are an opportunity for retailers to exercise power according to their market share and can make sustainability a priority in a way that does not rely on policy.

Because of consolidation in the food system retailers exert significant influence on other sectors, particularly wholesalers and processors. Consumer Expert 1 noted that retailers also have power in determining what food products are offered to consumers. The intermediary position of retailers was also described by all wholesaler respondents, noting that what the retailers wanted largely drove their offerings. Multiple processors also stated that retailer standards influenced policies and decisions at their company. The retailers interviewed noted the role that they had in selecting what products to buy from their vendors and distributors but in the context of carbon accounting policies, they expressed significant concerns about their ability to access data because they are so many steps removed from the point of production.

Consumers

As concern and awareness of the climate crisis increases, consumers are beginning to apply pro-environmental beliefs to their food purchasing decisions. The International Food Information Council (IFIC) is a nonprofit research organization that does research on sustainable food, food safety, and nutrition for the food and beverage industry. They regularly conduct rigorous surveys to analyze trends and attitudes around consumer behavior. In 2020, they conducted a survey about food production and climate change and in 2022 they conducted their annual Food and Health survey (IFIC, 2020; IFIC, 2022). Both surveys report that many Americans are concerned about the environment, connect food production with climate change, and take environmental impact into account when making some of their food and beverage choices. In the survey on food and climate, 70% of consumers reporting they were at least somewhat concerned about climate change, very similar to what Yale has found in their "Six Americas" survey, and 60% indicating they were concerned about how food contributes to climate change (Yale, 2023; IFIC, 2020). 19% of respondents said that concerns about climate change always affect what food and beverages they buy and 52% said their concerns sometimes affect their choices (IFIC, 2020). In the 2022 survey, just under half of respondents (42%-48) rated the following sustainability metrics a 4 or 5 when making purchasing decisions: knowing that the food was produced with animal welfare in mind, knowing the food was produced in an environmentally sustainable way, knowing the food was produced using farming technologies that seek to reduce the impact on natural resources, knowing that the workers who produce, distribute, or serve the food are treated in a fair and equitable way, knowing that the food or beverage was produced in a way that minimizes its carbon footprint/climate impact, and whether it has a recyclable packing (IFIC, 2022). In the 2020 survey, 35% reported that they would purchase a product if they found out that it was more environmentally friendly than their usual choice, and 29% said it would depend on the price and, overall, 79% of respondents said they look for environmentally friendly choices when shopping for food and beverages, significantly more than any other category of goods (IFIC, 2020). Although intentions and beliefs are not necessarily predictors of actual behavior, they are good indicators of social awareness and norms. These numbers show that consumers are aware of the link between food production and

climate change, creating the opportunity to leverage this awareness in efforts to reduce carbon emissions from the US food system.

Human behavior, like the food system, is highly complex. Early research attempting to create explanatory models, like early food system models, simplified variables in mostly linear pathways (Ramsey & Rickson, 1976; Ajzen & Fishbein, 1980; Hines et al., 1986). Generally, these models do not include crucial elements such as feedback loops, internal motivation, personal capacity, and external barriers. Kollmuss & Agyeman (2002) combined many of the variables in the previous simplistic models into a highly complex "model of pro-environmental behavior," with relationships and feedback loops between categories of variables and many possible internal and external barriers. The inclusion of barriers makes this model more useful when attempting to explain why there is a gap between values, attitudes, and intentions, and individual behaviors. Several external factors, including infrastructure, social and cultural factors, and economic limitations are combined in the Kollmuss & Agyeman model as the barrier "lack of external possibilities and incentives" (2002). These barriers offer multiple explanations for why the behavior of the consumers represented in the IFIC surveys does not always align with stated pro-environmental values and goals: are sustainable options always present; do consumers have enough money to purchase the more sustainable product; is there a sustainable alternative to an item that has significant cultural relevance for them, etc.

Most interview respondents who commented on consumer behavior noted similar barriers to sustainable food choices. The importance of price and familiarity were noted by respondents from wholesalers, consumer experts, and processors. There were also some respondents who saw information as key to explaining consumer behavior, Advocacy Organization 1 thought that carbon neutrality was easier than carbon accounting for consumers to understand and Data Researcher 2 and Processor 2 noted that consumers already have a great deal of information to process when making purchasing decisions. There is tension between these observations that consumers have limited knowledge and motivation to make sustainable choices, and the position noted by multiple processors, wholesalers, and retailers that consumer demand was one of the main drivers of their business decisions.

Individuals can act for change across different scopes, either as private individuals or as actors within organizations or governments. Cullerton et al. (2018) developed a pragmatic model for advocating for policy change in the public health realm. Increasingly, the public health implications of the climate crisis are being fully acknowledged as is the importance for acting at all available leverage points. This model can be applied to working for sustainable food systems as well. The core of the framework is investing in relationships with a diverse range of actors to increase the likelihood of efficacy and identifying a policy champion that can represent the desired policy change at all opportunities (Cullerton et al, 2018). This strategy is applicable across scales, equally relevant to citizens advocating for food systems change in their neighborhood and larger actors in the food supply change, such as farmers employing agroecological practices.

Moore et al. (2022) find that, with swift action, it is possible for the government to enact policies with a significant impact on emissions reductions. Although the Paris Agreement goal of 1.5C warming is likely out of reach, staying within 2C and 3C is seen as a reasonable goal. In their analysis of how to make this policy action happen, they identify "strength of public opinion" and "responsiveness of political institutions" as two of the most effective. Again, when looking for policy action, the path starts with smaller scale pushes for action.

Policy change must also include intentional action that reduces the power of oil and energy companies (Stokes, 2020). Legislation and policy are an opportunity to build the capacity of other industries in the public and private sector, as seen in recent public discourse about the distribution of funds from the Inflation Reduction Act (The White House, 2023). Stokes identifies unions and citizen-led initiatives as powerful in this process and notes the importance of building a unified, strong, and diverse network of actors that aligns with Cullerton et al. (2020). Individual cans also advance their interest in sustainability via their professional power. There are growing networks of people in the financial sector working to leverage their influence toward sustainability in the industrial food system (Good Food Finance Network, n.d.). In addition to exerting pressure on industry behavior, the financial sector can also play a role in funding the behaviors that are necessary for a sustainable food system. In 2021, the World Bank published *Food Finance Architecture*, highlighting leverage points throughout the global food system that are funding opportunities for investors (The World Bank, 2021). Transformative change can come about when there are enough interested individuals in positions of influence to structure policies that prioritize emissions reductions.

Network Visualization

To visualize the interconnectivity, and potential for leverages within the US food system, interviews within each sector were utilized to assess influential relationships. Through targeted questions within each interview, stakeholders identified which sectors had the greatest influence on their associated organization and sector, as well as the inverse. Subsequent answers were then analyzed to decipher both the directionality of the influence, as well as the nature of this relationship. All influential relationships are represented with arrows, with the frequency of mention for each relationship signified through multiplicity of lines within each arrow. Furthermore, the strength of influence on surrounding sectors, quantified by the frequency of mentions through which the sector was identified as the source of pressure, is represented by the size of the sector bubble. For instance, processors were named as the source of pressure 16 times, therefore, the associated bubble is 8 times the size of the "International Governments" bubble, which was only mentioned as having influence once. All identified vectors of influence, with their points of origin, reception, and a summary of the interview excerpt they were coded from, can be found in Table 2. Finally, the number of interviews within each sector that are represented in this graphic is signified by the "n=" quantity. While a disproportionate number of interviews fell into the processors sector, the majority of mentions took place outside of this sector.

Therefore, researchers concluded that although the additional data may skew the visualization slightly, the value of the increased quantity of identified relationships outweighed this threat.

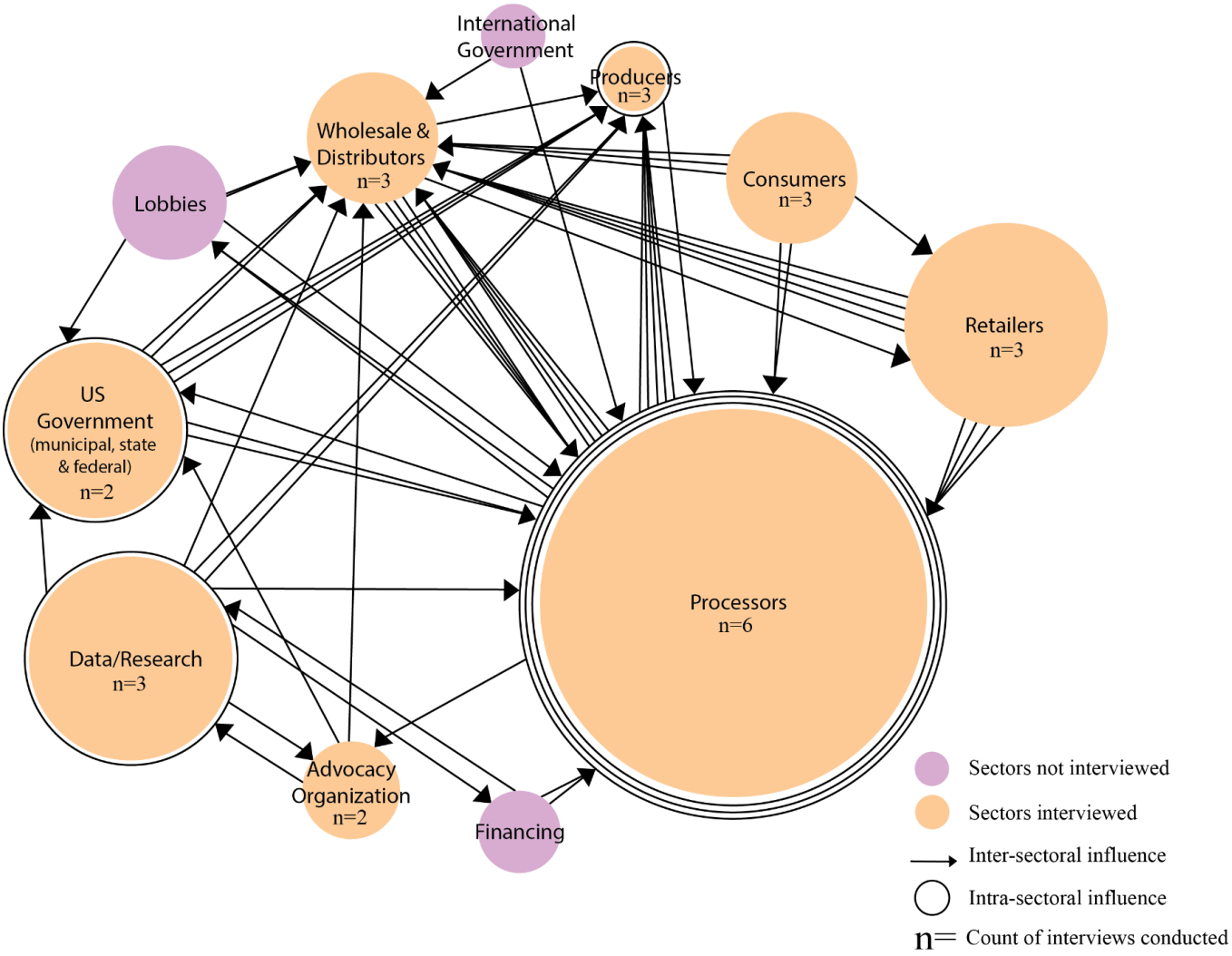


Figure (10): This figure visualizes relationship dynamics identified through sector interviews. The size of the sector bubble is proportional to the number of influential relationships mentioned within interviews. Therefore, the size represents the sector's influence on the overarching food system. Each line represents a single mention of a directional, influential relationship from one sector to another within an interview. Each open circle represents a single mention of an influential relationship between actors within the same sector. Frequency of occurrence is depicted by the number of lines within an arrow, or open circle.

Consumer influence on the system was found a total of 6 times. Influential relationships extended to processors (2), retail (1), and wholesalers (3). This influence primarily represented purchasing power, as increased consumer demand for food products representing low carbon footprints was expected to increase the adoption of both carbon efficient, internal practices such as energy efficiency, and the sustainable food product portfolios of processors, wholesalers, and retailers. A similar relationship is found for consumer demand for transparency. However, it was

noted through interviews that consumer influence is strengthened through citizen lobbies that can serve as an amplification tool for public opinion or demand of action.

Research and data processors were found to have influence on surrounding sectors a total of 9 times. This influence extended to other research and data processors (1), financing of technological advancements (1), government (1), advocacy organizations (2), processors (1), producers (2), and wholesalers (1). Vectors of influence extending outward from this sector primarily represented the gathering and processing of data that would be used by other sectors of the food system as a basis for their sustainable action. It is also important to note the influence that data and research processing organizations can have on the advancement of technology utilized through carbon accounting strategies. Such advancement lays the foundation for standardized and reliable data collection supporting the functionality of carbon accounting strategies for emissions reduction.

Financing was found to have 3 influential relationships on the sectors of the food system. This system element was not defined as a specific sector within the food system, but instead as a dynamic external factor that was mentioned to have a significant influence on the actions within the food system. The label, "financing" represents influxes in the stock market, private investors, and other streams of capital. This element was found to have influence over research and data processors (1), and processors (2). These relationships are representative of the power of investors within these sectors on their internal operations in relation to sustainability initiatives.

The United States government was found to have 8 influential relationships on the other sectors of the food system. This influence extended outward to other government actions (1), processors (2), producers (3), and wholesalers (2). Intragovernmental influence represents how the appointment or election of officials can impact the speed and scope of implementing environmental policies. Governmental influence on processors, producers and wholesalers is representative of the power of procurement and purchasing agreements, subsidies, and mandated operational procedures. Federal, state and local governments all support public entities that supply food, such as schools, prisons and parks. Therefore, the purchasing decisions to supply these entities has a significant impact on how and what sectors within the supply chain produce and sell. Furthermore, through the allocation of government subsidies, sectors within the supply chain are provided financial incentive to adopt practices that reflect the goals of the administration. An example of this relationship is displayed through the subsidies that reward food producers for adopting sustainable agricultural practices. Finally, through regulation, such as that displayed through FDA labeling requirements, sectors within the supply chain are influenced to adopt specific guidelines to protect human and environmental health.

The international government was also not directly interviewed in this research; however, it was found through interviews to have influence on the actions of the US food system 2 times, on processors (1) and wholesalers (1). These vectors of influence represent how laws mandating carbon reporting in other countries can have reverberating effects on the operations of multinational corporations that have bases within the US.

Lobby organizations are another sector not directly interviewed but found to have 5 notable influential relationships within the food system. These influences extended to government agencies (1), processors (2), and wholesalers (2). Lobbies were identified as a substantial source of both economic and political pressure. For instance, lobbies may pressure government officials to regulate labeling and processing, to maintain control over specific sections of the market. This influence was specifically identified in relation to the meat and dairy industries but can extend into other portions of the market as well.

Advocacy organizations were mentioned as having 4 influences on the food system, on research and data processing (2), government (1), and wholesalers (1). These relationships were identified as primarily financial, as they fund actions that are outside of government regulations and the capacity of individual actors to achieve specific goals in relation to sustainability. Additionally, it is noted that advocacy organizations spark technological developments, such as circular packaging, which can then be utilized by sectors to reduce their internal emissions.

Processors had the greatest number of influential vectors (16), with influence extending toward government (1), lobbies (1), advocacy organizations (1), other processors (4), producers (5), and wholesalers (4). This sector was found to have influence on the government through financial and lobbying power. This same relationship is reflected in the influence processors have on producers and advocacy organizations. Processors have influence intra-sectorally through market competition and the adoption of sustainable infrastructure or techniques. Processors also influence producers through purchasing decisions and contracts. Finally, processors influence the sustainable action of wholesalers through marketing, which enhances bottom-up demand, as well as through the development of large shipping contracts. This significant influence of processors on surrounding sectors, and the system overall, means that producers have significant potential to either advance or hinder the adoption of a carbon accounting mandate. Receiving political and financial support from large processors is therefore vital for the future of carbon accounting in the United States. If implemented on processors, they maintain the greatest influential power to change the actions of other sectors in the food system to adopt carbon accounting strategies.

Producers were only found to have 2 influential relationships on the food system: on other producers (1), and on processors (1). Education and equipment sharing is representative of the intra-sectoral influence. The influence from producers to processors is representative of how consolidated companies (those maintaining operations in multiple sectors) have market pressures to reach sustainability goals in relation to emissions reduction. Such companies are amongst those that do not neatly fit into one specific sector.

Retailers had 9 mentions of influence on other sectors, with the receiving end of the vector being processors (4), and wholesalers (5). These relationships all reflected pressures corresponding to an increased demand for sustainable action, and food products, from their associated customers.

Lastly, wholesalers were found to have 6 influential relationships in the system on processors (4), producers (1), and retailers (1). These relationships greatly reflect those

represented by retailers, as the rate of adoption of carbon accounting and sustainability techniques will be representative of pressure from their customers. Additionally, wholesalers influence producers to set and achieve science-based targets by adopting sustainable techniques.

Understanding the relationships between sectors allows one to better identify leverages through which carbon reduction strategies can be effectively implemented, as well as maximizing the scope of impact. Comparing the quantity of influential relationships originating from processors (16) , to those from producers (2), one can conclude that policies, or other strategic actions, implemented at the processor level are more likely to influence actions within other sectors compared to producers. For instance, a mandate on processors to implement carbon accounting strategies has the potential to influence the actions of other processors, lobbies, the US government, NGOs, producers, and wholesalers. On the other hand, this same policy implemented within the producer sector, may only have influence on the actions of other processors and processors. This discrepancy of influence on the actions of surrounding sectors is representative of the mismatch between historical approaches to food emissions reduction that have targeted producers, instead of the largest emitting or influential sectors such as processors.

The initial policy proposal for this project was to implement a carbon accounting mandate at the wholesale or distributor level (grouped together within this report). However, through this analysis, one recognizes that while this sector has substantial influence on the overarching system, it is not the primary source of influence. Utilizing the processor sector as a leverage for change through targeted policies presents an opportunity to maximize emissions reduction through the sectoral relationship dynamics of the US food system. Through stakeholder interviews, processors were found to influence the actions of other sectors through purchasing power; funding lobbies, advocacy organizations, and research; marketing, and transportation. If strategically motivated to reduce carbon emissions through carbon quantification, accounting or transparency mandates, processors will apply pressure through these channels to reduce the emissions of partner organizations, therefore reducing net emissions of the food system.

Influencer	Influenced	Summary of Excerpt	Interview Sector
Consumers	Processor	Consumer demand for or against certain ingredients/products influences how much processors produce or include	Processor
Consumers	Processor	If there is any indication that consumers support and care about a specific action/issue, will adjust operations in order to maintain consumer-centric front	Processor
Consumers	Retail	Initiatives are put into place to help consumers achieve their own goals	Wholesale
Consumers	Wholesale	Social issues (i.e. animal welfare) when they become large enough factors in consumer decision-making, will be avoided by sourcing from processors that avoid these issues.	Wholesale
Consumers	Wholesale	Consumer demand for low-carbon products, changes retail demand, therefore pressuring wholesale to reduce/quantify emissions	Wholesale
Consumers	Wholesale	Consumer demand for information determines actions related to transparency	Wholesale

Research/Data	Research/Data	Research organizations influence one another by building off of previously collected data, or repeating methodology	Consumer Research
Research/Data	Financing	Consumer research determines where investments in technological and system changes are implemented	Consumer Research
Research/Data	Government	Research influences policy development at all levels	Consumer Research
Research/Data	Advocacy Organization	Research influences programmatic decisions within advocacy organizations	Consumer Research
Research/Data	Advocacy Organization	Data informs actions of advocacy organizations	Consumer Research
Research/Data	Processor	Existing and new policies mandate how processors operate	Processor
Research/Data	Producer	Data informs producers about sustainable practices	Consumer Research
Research/Data	Producer	When new equipment or technology comes onto the market, salesmen will go to farms to sell, under the assumption that use will optimize production	Producer
Research/Data	Wholesale	Sustainability targets are identified through contracted researchers/consultants	Wholesale
Financing	Research/Data	Financing through partners directly determines where investments are implemented	Consumer Research
Financing	Processor	Investors want to see emissions reduction, resulting in the adoption of more sustainable practices within organization	Processor
Financing	Processor	Politicians, private equity, bankers etc. saturate a specific market with financial investments, processors are subsequently pressured financially to shift	Processor
Government	Government	Sustainability positions within local governments are often appointed by the mayor	Government
Government	Processor	State enforces FDA labeling criteria	Processor
Government	Processor	As more scientific data supporting climate change and highlighting significant actions, processors will have to change their actions	Processor
Government	Producer	Local policy makers can influence production practices through policy and education campaigns, as well as expansion of local food movement	Government
Government	Producer	Develop relationships with local producers, and encourage sustainable growing practices for municipal investment	Government
Government	Producer	Government funding and regulatory action influences how maintain and harvest agricultural land	Producer
Government	Wholesale	Procure products for events and publicly distributed goods through vending and parks operations, from sustainable suppliers (wholesalers)	Government
Government	Wholesale	USDA and FDA regulate food labeling procedures and content	Wholesale
International Government	Processor	Laws mandating carbon reporting in other countries	Processor
International Government	Wholesale	International laws change company standards, which result in changes across the board.	Wholesale
Lobbies	Government	Anti Regulatory lobbies pressure government officials to loosen production guidelines to appease the fast food and hotel industries	Consumer Research
Lobbies	Processor	Anti Regulatory lobbies suffocate processor action to maintain financial and lobbying support	Consumer Research

Lobbies	Processor	Lobbyists pressure government officials to regulate labeling, and processing to maintain control over specific sections of the market (i.e dairy against plant-based labeling)	Processor
Lobbies	Wholesale	Trade and agricultural lobbies pressure companies throughout the chain to adopt various strategies, if these groups demanded certain emissions reduction strategies, wholesalers would almost have to comply	Wholesale
Lobbies	Wholesale	Groups that public consumers belong to, i.e. lobbying groups and citizen lobbies begin to shape their purchasing decisions, shifting demand from customers (retailers)	Wholesale
Advocacy Organization	Research/Data	Directly fund data operations	Consumer Research
Advocacy Organization	Research/Data	Provide funding, and consumer client base that determines direction of retail investments	Consumer Research
Advocacy Organization	Government	Maintain funding to perform actions and activities that are out of government capacity, then translate that back into government bodies	Government
Advocacy Organization	Wholesale	Technology developments through advocacy organizations such as circular packaging, impact what's possible for wholesale reduction strategies	Wholesale
Processor	Government	Corporations influence state and federal level of government through financial power	Processor
Processor	Lobbies	Corporations provide funding and research for lobbying	Processor
Processor	Advocacy Organization	Corporations influence research and lobbying power of advocacy organizations through trade associations	Processor
Processor	Processor	Changing operational structure, or adopting new technologies within own business to reduce emissions	Processor
Processor	Processor	(Same relationship as above)	Processor
Processor	Processor	If multiple processors have similar sustainability goals and suppliers, can work together to implement reduction strategies upstream that will benefit them both	Processor
Processor	Processor	If the majority of food processors begin operating in a certain way (i.e. adopting specific sustainability goals), will need to adjust operations in order to stay competitive in the market	Processor
Processor	Producer	Ability to influence what farms they source from, as well as the practices of farms with long-term contracts	Processor
Processor	Producer	Sourcing from producers with sustainable practices already in place	Processor
Processor	Producer	Have the opportunity to procure from producers that are meeting specific sustainability goals	Processor
Processor	Producer	Have the opportunity to procure from producers that are meeting specific sustainability goals	Processor
Processor	Producer	Source from sustainable producers, and assist in implementing carbon quantification/accounting protocols or technologies	Processor
Processor	Wholesale	Marketing from large corporate processors influence demand from bottom up which influences how wholesalers need to perform to stay competitive	Consumer Research
Processor	Wholesale	Influence large shipping contracts through the wholesale sector through transportation and localized distribution.	Processor
Processor	Wholesale	Purchasers within the processing company keep track of the supply chain, and associated issues. When ingredients with controversy (i.e. palm oil) can be avoided, will reduce its use. This reduces net carbon emissions of wholesale	Processor

		products	
Processor	Wholesale	The actions of processors significantly reduces the emissions of the products sold at wholesale, therefore there is interest going both ways to reduce	Wholesale
Producer	Processor	If large, multilateral suppliers (i.e Walmart) require specific standards, have to meet in order to maintain relationship	Processor
Producer	Producer	Producers share techniques and sometimes equipment to optimize production	Producer
Retailers	Processor	If customers (retail or wholesale) make sustainability goals, processors have to figure out a way to meet the mark in order to maintain the relationship	Processor
Retailers	Processor	(Same relationship as above)	Processor
Retailers	Processor	(Same relationship as above)	Processor
Retailers	Processor	Collaborate with retail to determine what would be the best way to achieve mutual goals	Processor
Retailers	Wholesale	Retailers make decisions about what products they sell based on price, if 2 similar products are being offered in the market, will source from cheaper wholesaler	Retail
Retailers	Wholesale	Initiatives are put into place to help customers (retailers) achieve their own goals	Wholesale
Retailers	Wholesale	If customers (retail or wholesale) make sustainability goals, wholesalers have to figure out a way to meet the mark in order to maintain the relationship	Wholesale
Retailers	Wholesale	(Same relationship as above)	Wholesale
Retailers	Wholesale	(Same relationship as above)	Wholesale
Wholesale	Processor	(Same relationship as above)	Processor
Wholesale	Processor	(Same relationship as above)	Processor
Wholesale	Processor	(Same relationship as above)	Processor
Wholesale	Processor	Pressure distributional partners to initiate/follow sustainability goals	Wholesale
Wholesale	Producer	Pressure suppliers to set and achieve science-based targets	Wholesale
Wholesale	Retailers	Distributors are closest collaborator	Retail

Table (2): Summary of all relationship data collected from sector interviews and displayed in the network visualization. The first column represents the origin of the vector, and the source of influence. The second column represents the receiving sector of the vector, and influence. The third column summarizes the excerpt that the influence vector represents. The final, fourth column is the sector within which the interview was intended to represent.

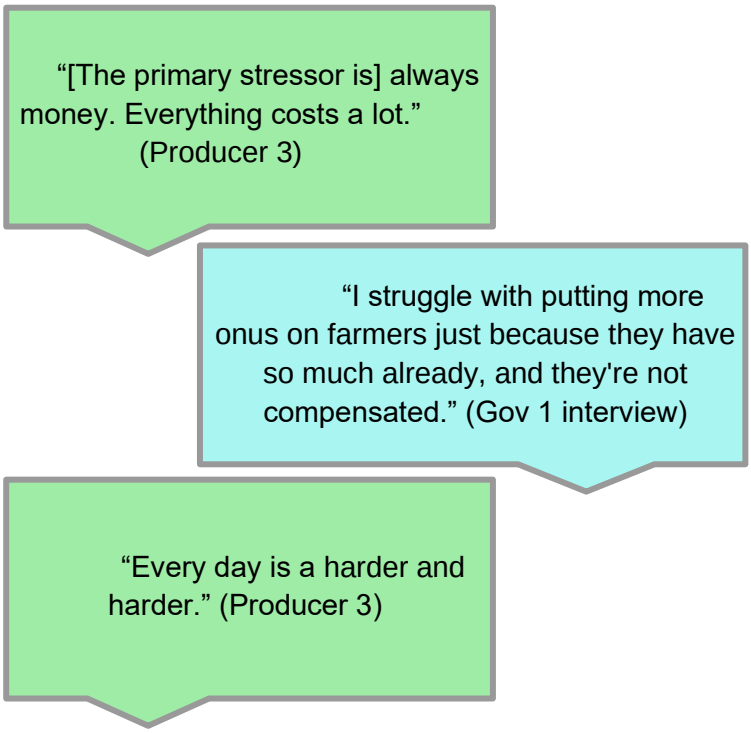
Discussion

Shifting the Focus

As the literature review, qualitative interviews, and network visualization demonstrate, food production in the US is a highly complex system, with interconnections and dependencies between the sectors along the supply chain. With this in mind, recommendations in this report focus on strategies that leverage connections between sectors, distributing pressure through the entire system to advance emissions reduction goals. Figure 2 shows 82% of GHG emissions

coming from the on-farm production of food, creating a focus on farmers for reducing emissions that is seen in many climate change mitigation strategies, both national and international (Riensche, B., & Jakhar; World Bank, 2021). However, this approach ignores the interconnectivity, power, and influence that other sectors wield on producers.

Most importantly, it belies the reality and implications of consolidation and vertical integration of the food system, both within the US and globally. Consolidation has happened across the agricultural system and is assessed by how much of the industry is controlled by the top agribusiness forms, known as the CR4 index (Hendrickson et al., 2018). For instance, in over the last 60 years, the four largest companies have grown from controlling 25% of non-poultry production to more than 50% (Hendrickson et al., 2018). Vertical integration occurs when companies that previously sold inputs and or outputs to each other merge into a single entity (Hendrickson & James, 2005). There are two key effects this has on producers: "[f]irst, it constrains…decisions of farmers by restricting choice options or the types of decisions they can make…Second, it constrains… the choices of farmers by forcing them" into particular production practices (Hendrickson & James, 2005). One of the ways these constraints occur is through the influence of industry power in lobbies and trade organizations, discussed earlier, as the large companies are able to drive policy and regulation that are friendly to their modes and scales of production.



(Excerpts pulled from stakeholder interviews)

Farmers have very little power in the system due to the small profit margins associated with the profession ("Corporate Control in Agriculture," n.d.). This leaves many farmers with little to no resources to make independent decisions about their growing practices. As mentioned

in the discussion on equity issues, the majority of farmers in the US– the 89% of farmers responsible for 20% of total production– have a negative net income from farming (Nestle, 2020). Combining this information with the power dynamics in our network visualization, we have identified leverage points that either reduce reliance on producers or ensure that necessary resources are included in implementation plans so they can transition practices to reduce emissions. Specifically, processors are a likely point of intervention because of their level of influence and resources for implementation. They have influence to change consumer habits, modify sourcing, and identify possible carbon reduction areas in the supply chain. Shifting the focus of emission reduction from farmers and producers onto the processors maximizes the potential for carbon emission decrease and creates a more equitable solution.

Feasibility of a federal carbon accounting mandate

(Artistic rendition by: Hannah Peplinski)

For the purpose of this research, feasibility refers to both the policies projected capacity to pass through the United States legislative process, as well as its potential to significantly reduce net greenhouse gas emissions within the US food system. As the primary purpose of this research was to identify a strategy to influence components of the food system to *significantly* reduce emissions within the US food system, researchers evaluated the projected effect of the proposed policy in relation to alternative strategies.

The policy proposed for this research was to federally mandate US food distributors to utilize carbon accounting. Advocacy for this proposal operates under the assumption that food distributors represent a prominent leverage that can be utilized to expand the adoption of carbon quantification and reduction strategies across all sectors of the food system. However, through a comprehensive analysis of the current state of carbon accounting in the US, the policy climate in relation to carbon accounting in the US and the network dynamics of the US food system, the feasibility of this mandate came into question. While countless factors could influence the feasibility of this policy, 5 key components have been highlighted in this report: barriers for the collection and reliability of associated data (data barriers), lacking regulatory structure and financial resources for policy adoption (resources and regulation), the potential for corporations to misrepresent data for financial gain (greenwashing), prominent political barriers for legislative success (political contention), and the risks of investing time and resources into this policy in relation to others with greater potential for emissions reduction (opportunity cost).

Data Barriers

A federal carbon accounting mandate would require all food companies to calculate the carbon emissions of their products. As mentioned previously, LCA data has limitations. The interviews clarified the limitations and downsides of life cycle assessment from the point of view of the company. In any LCA, some inputs into the food system are not easy to measure and quantify. As Interviewee 11 noted, soil erosion and acidification are complicated to assess (Data Researcher 2). Two of the interviews with processors reaffirmed that LCA's are expensive, take time, and that they are not done for all products at their respective companies (Processors 1 and 2). For example, one of those interviewees spoke about how full LCA's are only run-on products targeted for marketing or advertising plans. For instance, if a company wanted to make claims about one product's sustainability compared to another company's same product (Processor 1). Another barrier of using LCA for carbon emission reduction is that small changes in a product's supply chain render the LCA inaccurate (Processors 1 and 2). These challenges highlight the difficulty of enforcing a carbon mandate. It would be hard to mandate how often companies would be required to quantify emissions or how long they would have to finish the assessments. In addition to enforcement limitations with LCA, there is also the challenge of completing the LCA itself.

A significant challenge to using a life cycle assessment methodology for carbon reduction is that the methodology may not be developed enough to be used to enforce a federal regulation. This is because there is not yet an agreed-upon national framework for conducting standardized LCAs and therefore different companies run them with different criteria ("Limitations of LCA," 2018). Part of the reason there are different approaches to LCA is because not all of the data needed is known or obtainable, so many teams rely on averages, assumptions, and generalizations to complete the analysis ("Limitations of LCA," 2018). According to Data Researcher 3:

> "You can't measure everything, so it relies on models and averages. And one of the things about food systems is … if you take the example of beef … the measurements are based on industrial models. There's been less study of intensive rotational grazing and other models of livestock production. Life cycle analysis … it's very useful in terms of trying to improve our understanding but … we have to keep in mind that they are models, and they don't always capture everything."

This is not to say that LCA are not useful, they are important, and Data Researcher 2 admits that "there's generally a lack of appreciation of the level of data quality that we're currently working with," but the consensus is that it is not yet accurate nor attainable enough to be used by all food companies in the country.

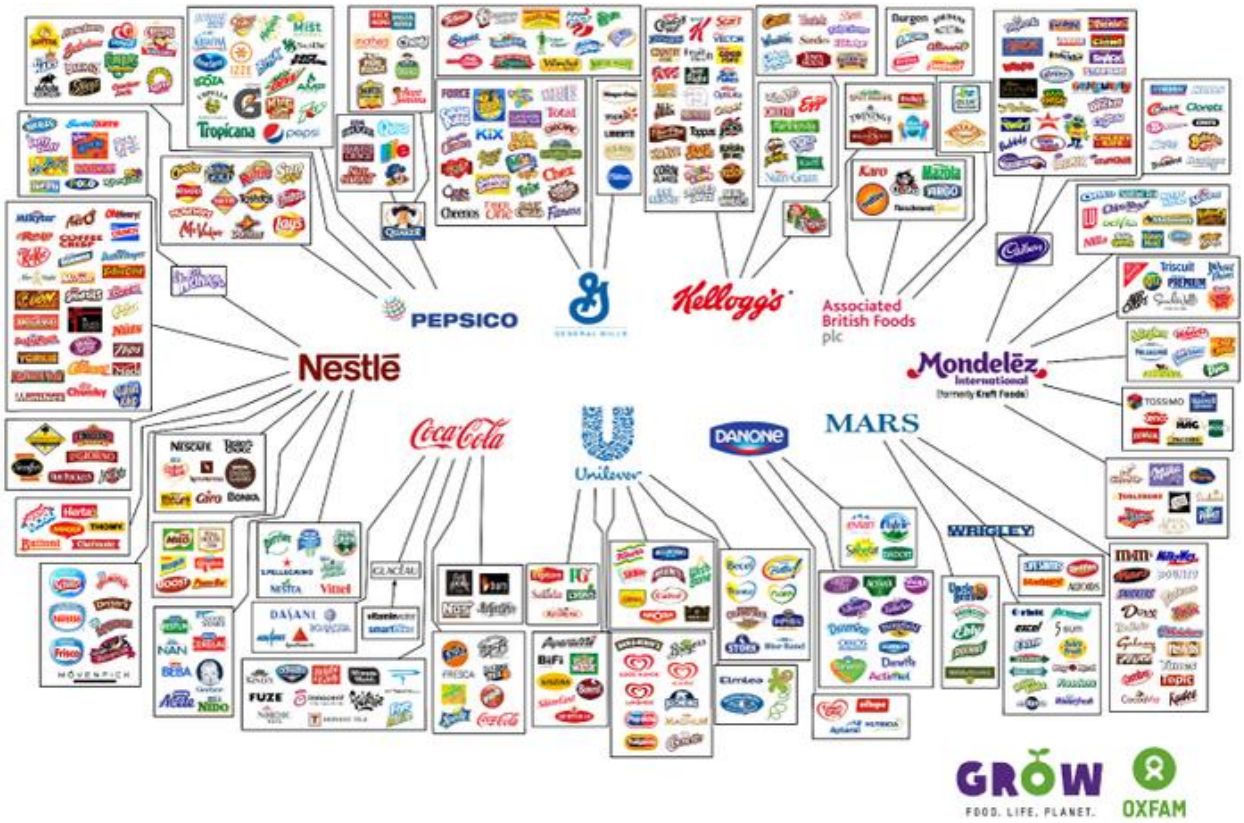


Figure (11): This visualization shows 10 food conglomerates and the companies that they own. The purpose of the image is to show how vertically integrated the current food system is. It is from a Business Insider Article called “These 10 Companies Control Everything You Buy” by Kate Taylor.

The data would be even harder to attain for smaller food companies, and thus making it difficult for them to abide by the same regulations as larger companies. The current food system in the United States is largely controlled by a small number of companies (see image below). There are also conglomerates in other aspects of food production as well, “Just four firms have over half the market for seeds, chemicals, and farm machinery for the entire world… [they are] continuing to get even bigger and they are reshaping regulations that affect nearly every aspect of society” (Data Researcher 3). The companies in Figure 11 are those that have the means and power to not only conduct LCA’s for their products, but also to lobby against the potential mandate. A mandate would be unlikely to pass, unless these firms saw it as an opportunity to buy out or decrease the number of smaller companies (Data Researcher 3).

> “Regulations are a really effective way to provide advantages to larger firms. You know, it sounds like it's a level playing field, but if you look at regulations around food safety, for example, meat processing, that's one of the most concentrated food industries, just four firms control over 80% of meat processed beef processing in the US, and that's because it has become so difficult to comply with regulations, except at a very large scale. “ (Data Researcher 3)

There is a possibility that the carbon emissions mandate would not reduce emissions, but further the aggregation of the food system by making it harder for smaller firms to thrive. Aside from just the who and what of regulating such a mandate, there is also the question of how. An investment induction for employees at the federal level and company level would be required so that they would clearly understand the goal and nuances of the policy. With a lack of understanding of LCA and its use, "there is a lot of education that's necessary because people don't really understand units or … that there is a carbon cycle or… what carbon really means, and so a lot of the work would probably have to be in education people on how to interpret that information" (Data Researcher 1). Prior to the lobbying and enactment of the carbon mandate, an education campaign would need to be conducted to ensure both governmental and company leadership fully understood the requirements.

Resources and Regulation

There are currently 20 federal regulatory agencies, and it is not clear which would have the authority to regulate a proposed mandate. The resources necessary to enforce such a mandate would be extensive as well. Federal employees and private companies (or NGOs) to conduct LCAs as per the policy would require money and time. These same concerns over resources and regulation were reiterated by the interviews conducted with our stakeholders working in the government sector. One governmental interviewee who works on sustainability efforts spoke of worries regarding enforcement due to low employee numbers, budget constraints, the lack of a tool to help companies calculate emissions, and lack of knowledge to fact-check the reports from companies (Government 3). While this person was working at the municipal level, the same concerns were mentioned at the federal level, as well as a lack of current policies around carbon emissions.

> "They are not coordinated … [at the] federal level. That would require a robust standard and computational structure. I mean the USDA certainly Isn't asking any questions that are directly related to carbon emissions in their census ag efforts at this point. A lot of the information that they ask is relevant, but it's not directed by that outcome. So there are pieces that get missed." (Data Researcher 2)

According to the United States Department of Agriculture website on greenhouse gas accounting and mitigation, the Department is focused on reducing carbon emissions through "conservation and land management practices" ("Greenhouse Gas Accounting", n.d., para. 1). The organization does have a document for explaining their carbon emission estimation methods; these methods include basic estimation equations, models, field measurements, inference, and hybrid estimation approaches (a combination of the others) (Eve et al., 2014). Without getting into the specifics of each method, it is crucial to note that so many options are available in order to "balance user-friendliness, data requirements, and scientific rigor in a way that is transparent and justified" (Eve et al., 2014, p 2-12). Based on this document, people and companies are calculating their emissions differently, which has potential to limit the success of a mandate. An interview with a person at a processing company noted that if "everybody's … measuring

emissions their own way, then we're not stepping on the same scale and we're getting different numbers. It can't really compare" (Processor 4). It is also worth noting that the document has not been updated since 2014. This further illustrates the missing guidelines for calculating emissions at the national level.

Greenwashing

With the described combination of data barriers and regulatory challenges, there is a possibility that such a national carbon emissions mandate may result in greenwashing. Greenwashing is when a company misleads people into thinking a product is more environmentally friendly than it is (Gibbens, 2022). Greenwashing can include outright lies to consumers, or it can be a factual spin. One example of greenwashing that resulted in a lawsuit from the Federal Trade Commission was when Walmart tried to sell rayon fabric as bamboo. One example of a factual spin is carbon offsets. Carbon offsets are "tradable 'rights' or certificates linked to activities that lower the amount of carbon dioxide in the atmosphere" (Gurgel, 2022, para. 1). Carbon offsets are bought by companies as a way to decrease their net emissions without reducing their own carbon footprint; examples include tree planting or renewable energy investment (Gibbens, 2022). Without accurate, granular data, a standard LCA methodology, and a set regulatory practice for a federal carbon accounting mandate, there is a possibility that companies will report lower numbers, switch to a more sustainable supply chain for a short time or greenwash in some other way. A retailer/ procurement company testified to a similar concern, that the regulation "just incentivizes them [corporate actors] to get better quickly at understanding how to manipulate the equation" (Retail 3). While there is not a clear or easy solution to greenwashing, a federal carbon accounting mandate would need a way to address the possibility.

Political Contention

When there are many actors at play in the food system, political contention naturally grows and evolves over time. Food system actors, all with different priorities and resources, are pitted against each other with one side pushing for sustainability efforts and the other doing everything they can to block those efforts to maximize profits. Data collected through interviews of this project support this finding. Multiple interviewees noted that sustainability remains controversial in US politics. This persists following the spread of distrust, and anti-science rhetoric spread throughout the Trump presidency, and was broadly adopted by members of the Conservative party (Webb et al., 2022). This coupled with the fact there is a revolving door with Congress and multinational company's lobbies, creates a highly contentious political environment. (Data 2, Advocacy Org 2, Ret/Proc 3). This contention then ultimately leads to difficulties gaining majority support within both the US House and Senate to successfully pass climate legislation.

Additional pressure and contention are added through the influence of lobbies and trade organizations. Actors within these sectors have extensive power over the market through consolidation, and subsequent power over political action through financing. Additionally, these actors exert power by undermining traceability and legitimacy in sustainable and science-based targets (Producer 2). This results in both the slowing of sustainability adoption, as well as the development of consumer mistrust in the validity of emissions disclosures. Alternatively, some multinational corporations are finding ways to reach science-based targets to utilize as an edge within the market, as they can then reinvent their brand to be "sustainable". Such producers are also likely to express disfavor for policies requiring all actors within their sector to calculate and report, as it would subsequently remove this competitive edge, and affect profits.

Finally, interviewees noted concern that policies mandating carbon accounting would establish new barriers to entry of smaller firms, resulting in further consolidation (Data 2 and Data 3) In short: timing and multi-sectoral collaboration are integral in the success of a carbon accounting mandate. Government 1 interviewee noted that given the current political context, a carbon quantification mandate would be extremely unlikely to be passed and implemented on a significant scale with an achievable scope, without cooperation of such factors (Government 1).

Opportunity Cost

Investing time, resources and labor in the passing of a carbon accounting strategy, has potential to draw such resources away from alternative strategies. Therefore, the opportunity cost of promoting this policy would represent all alternative policies that could have been implemented utilizing these resources and may have a great impact on the reduction of food emissions throughout the US. A mandate that focuses solely on quantifying emissions is not the same as a mandate that quantifies and reduces emissions. Consistently our interviewees suggested that the federal carbon accounting mandate would require heavy resources and have a small impact. Focusing solely on targeted emissions means that with growth, emissions will continue to rise (Government 1). Because of the limited potential impact of a carbon quantification mandate, resources that could have gone to building system resiliency are 'wasted' (Data Researcher 2). The emphasis on carbon itself takes attention away from other sustainability issues (Data Researcher 3). For instance, quantifying carbon emissions takes too long for an already understaffed local sustainability office (Government 3). To truly invest in a quantification mandate at all scales, there would need to be an investment in creating a comparable agency/team for food system calculations (Government 3). In addition, there are other ways to calculate sustainability and, unfortunately, that is not being captured in most LCA models (Data Researcher 3). The LCA perspective pushes us towards environmental efficiency and shifts the regulatory regime to creating carbon quantification labels as opposed to tackling actual unsustainable practices (i.e. concentrated animal feeding operations) (Advocacy Organization 2). Putting too much emphasis on quantification as a solution takes away from resources which relate to the opportunity cost. As one data analyst noted, the question then becomes whether or not those who interact with the food system understand these complex trade offs when deciding to implement a carbon quantification mandate (Data 3). Given the other

challenges and barriers to adoption of the federal policy, the opportunity cost would be high. If the resources were put elsewhere, such as into the alternative leverages suggested below, then there is a potential for more reduction.

Equity and Environmental Justice Concerns

Sustainability is broadly understood to encompass social and economic factors in addition to environmental consequences. Given this, considerations of sustainable food are not only about reducing emissions. (Purvis et al., 2019). In addition to environmental harm, the Food and Agriculture Organization of the United Nations (FAO) recognizes that the current system of global food production has negative impacts on myriad aspects of daily life, contributing to poverty, food scarcity, and poor diet (Bilali et al., 2019). Within the framework of sustainability, the FAO works to achieve poverty reduction, food security, and nutrition working within the social, economic, and environmental parameters of sustainability (Nguyen, 2018). Similarly recognizing the increasing emphasis on social and environmental outcomes in food systems analyses, Béné et al. (2018) call for components of production, processing, and distribution that are currently treated as externalities to be transformed into positive feedback mechanisms (Béné et al., 2018) They also note a shift in the contemporary understanding of food systems, recognizing that nutrition concerns are now seen as equal to basic food security (Béné, 2018). In its 2020 High Level Panel of Experts (HLPE) report, which creates a vision for food security in 2030, the Food and Agriculture Organization of the United Nations (FAO) updated its position on food and nutrition security, stating that pursuing a sustainable food system is the best way to also secure food and nutrition security (HPLE, 2020). With this in mind, an exploration of the utility of carbon accounting in reducing emissions from the US food system should also consider the intersections such a policy would have with equity and justice as it relates to food and nutrition security.

This progression is visible in the evolution of food systems models, which have become more complex and holistic in recent years and underpin sustainability goals across scales. Sobal et al. (1998) developed an "integrated conceptual model of the food and nutrition system," drawing on mixed methods to move beyond previous simplistic, single-sector linear models. This model focuses on how raw materials move through the food system to contribute to nutritional outcomes and acknowledges that the food system also interacts with biophysical and sociocultural contexts (Sobal et al., 1998). A more recent assessment of food systems analyses, Bouwer et al. (2020) reviews 32 food systems studies and categorizes them into four different orientations. Their definition of a food system comes from the UN Committee on World Food Security, and they use the HLPE 2017 plan as the base of their analysis (Brouwer et al., 2020). This definition expands Sobal et al. (1998) to include social, economic, and environmental outcomes as part of the system, and mirrors FAO goals (Brouwer et al., 2020). The analysis describes four different orientations common in food systems studies: supply oriented (focused on efficiency), midstream oriented (focused on the value chain linking producers and consumers), demand oriented (focused on traditional consumer demand pressures), and systems

oriented (focused on governance) (Brouwer et al., 2020). The points of view of each of the four orientations are important when making policy or alternative leverage recommendations.

It is imperative to maintain the importance of food access and nutritional security when engaging with the models and components of the food system that are more explicitly about economics. Many efforts to transform the US food system center on the premise that companies must see a financial benefit to justify the resources required to adopt sustainable practices and policies, shifting focus toward economics and away from social and environmental needs (Béné et al., 2020). Food justice combines the priorities of sustainability, food access, and nutrition security and argues for their primacy, hoping that the needs of people will be more important than the business considerations (Alkon & Agyeman, 2011). Working for food justice also recognizes the complexity of the food system and includes the priority that the benefits of sustainable food systems –social, economic, and environmental– are shared by all (Alkon & Agyeman, 2011). This means that, not only does a sustainable food system provide nutrition for all, it generates adequate livelihoods for all those involved in production, processing, wholesaling, and retailing as well (Alkon & Agyeman, 2011). Carbon accounting can be a powerful tool for reducing emissions but achieving carbon neutrality or zero emissions cannot be the only goal of sustainability efforts. When focused on balance sheets, emissions offsets can give the impression of reductions when in reality they are just shifted to other sectors, industries, or more vulnerable populations (To the extent that carbon accounting focuses solely on emissions data, it runs the risk of obscuring the other elements needed for a sustainable food system.

Equity and justice issues were mentioned by interviewees in five sectors across nine interviews. At least one respondent in processors, consumer experts, data researchers, government, and wholesalers talked about equity and justice within the food system or more specifically about the intersection with carbon accounting and a potential federal mandate. Although only about a third of respondents touched on these issues, they detailed many concerns, providing a similar number of coded excerpts as other topics covered by many more interviews. The three main themes that arose in the excerpts were concerns that: increased costs would be a burden on low-income families, small and medium-scale producers do not have the resources to comply with additional regulations, and that other important sustainability factors such as worker rights are not included in carbon accounting processes.

For instance, they described how increased costs associated with carbon accounting may be passed on to consumers, which would "put a bigger burden on lower income populations that already have a much higher percentage of their income going to food" (Consumer Expert 1). Increased food spending has a disproportionate impact on people experiencing other economic hardships, such as unaffordable housing (Kirkpatrick & Tarasuk, 2011). This would have negative social and economic impacts, reducing food access and nutrition security, especially among already vulnerable populations.

There could also be significant negative impacts on non-commercial farmers if carbon accounting policies targeted on-farm production for regulation and reductions. The USDA

classifieds 89.1% of farmers in the US food system as small, with less than $350 thousand in gross cash farm income (GCFI) before expenses (Kassel, 2023). After expenses, these farmers do not make any net income from their farming, relying entirely on off-farm income for their financial needs (Kassel, 2023). Less than 20% of total farm production comes from these small farms. The majority of production comes from large scale farms that have more than $1 million in GCFI or non-family farms and earn more than $400 thousand a year from their farm activities (Kassel, 2023). These highly profitable farms make up less than 6% of all farms and just over 60% of production (Kassel, 2023). With such disparate conditions across scales of farmers, any carbon accounting policies that target producers would have to factor in these different strata across the sector.

Sustainable food touches on many parts of the ecosystem and human society. As described above, social, economic, and environmental aspects are all important, and there are significant goals for social sustainability that are not present in present carbon accounting data. Processor 3 explained their concerns about a carbon accounting mandate in relation to equity concerns, touching on many of the points brought up by other respondents:

> A greenhouse gas metric alone gives me a great pause because it's telling a very incomplete story. Even an environmental metric that's just the environment, but includes deforestation and other things, and biodiversity is also a pretty incomplete story. The food system is complex, and so it's different from the others. It's different from energy. And so, we always remind people of that - policymakers and otherwise. There's a lot of people that touch agriculture as part of their work. It is culturally relevant, you don't [want to] get to a point where you are saying that people's cultural foods are bad choices.

Moving forward, developing ways to integrate additional factors into carbon accounting or combining them with other metrics should be a priority to shift food system sustainability metrics to incorporate social, economic, and environmental impacts (Unerman et al., 2018).

Alternative leverages for intervention

Invest in carbon accounting data

A reemerging theme throughout this research was the limitations of Life Cycle Analysis data. As this information is the foundation of carbon quantification and accounting as a technique to calculate and reduce emissions, the validity of any carbon emission reduction policy is heavily reliant on the validity of LCA data (as discussed in data barriers).

> “The biggest challenge is like I'm selling an ingredient, but that particular food probably has ten ingredients, and if all ten ingredients don't have the level of life cycle analysis data you get [an incomplete carbon footprint] of the product (Wholesale 2).

Therefore, before mandating, the federal government needs to first establish a standardized protocol for calculating food emissions in all sectors of the food system. $300 million of funds from the Inflation Reduction Act were allocated toward the development of the Greenhouse Gas Inventory Assessment Program - which establishes carbon accounting standards for food producers - through the USDA. This program, with continued investment and support can lay the necessary groundwork through which ambiguity and approximation within the development of LCAs can be minimized. Utilizing the 2023 revision of the Farm Bill to allocate additional, and lasting funding for the development of this, and related programs, is vital in the success of carbon accounting as a tool for food emissions reduction. Additionally, this program should be expanded to be outside of the sole scope of the USDA regulatory process in order to establish standards beyond agricultural production. Defining, and regulating consistent criteria for analyzing and reporting on the emissions for carbon, carbon dioxide and methane throughout the entirety of the food system is vital for the lasting success of accounting policies.

Through additional regulation to disclose emissions data, or through market competition, carbon accounting can become a trusted tool for emissions reduction. This recommendation is directly reflective of interview excerpts calling attention to existing leverages for changing the food system to become less emissions intensive. Wholesaler 1 additionally recommended that assigning a single government entity such as the EPA, USDA or FDA would increase ownership, consistency, and accountability in relation to the quantification and accounting of food emissions. This would ensure that companies employing carbon accounting could not skew data in their favor, and "greenwash" the public. Interestingly their recommendation directly combats the feasibility barriers relating to data, resources and regulation, and greenwashing.

An alternative leverage, expansion of the Greenhouse Gas Inventory Assessment Program would utilize government regulatory power as a leverage for effecting change throughout the system. Once trust is built between the associated carbon footprint data and consumers, consumers could then utilize purchasing power as a leverage to support food products and their associated businesses that reflect sustainability goals.

Use LCAs for targeted reductions

Policies for targeted reductions that utilize LCA data are a promising alternative to a policy at the federal level or one that applies across the entire food system. Review of the LCA process and interviews across sectors revealed significant barriers to using carbon accounting in a broad application. As noted previously, conducting an LCA is time and resource intensive, making it infeasible or burdensome for many actors across sectors ("Limitations of LCA" 2018). Data researcher 2, data researcher 3, and processor 1 all noted these limitations and suggested that LCA data would be more useful for "identifying where hotspots are " and making reductions at specific points in the supply chain. Additionally, the breakdown of carbon emissions in the food system in Figure 2 offers a possible starting point for target emissions reduction in the livestock sector, as 31% of emissions come from livestock or fisheries and a further 6% are from the production of feed for livestock. Interviews with wholesaler 3, retailer 3, and consumer

expert 5 also referred to target use of LCA data, specifically identifying meat production as the most obvious target for emissions reduction. Land use contributes 24% of emissions from global food production, indicating that practices better suited to soil conservation and reducing nitrogen runoff can also be a target of emissions reduction policies.

State-level carbon accounting mandate

Building from the state policy landscape, a state-level carbon accounting mandate is an alternative leverage that does not require action at the federal level and could have significant impact on carbon emissions from the US food system. California's Proposition 65 models the structure and influence that a state-level carbon mandate could have. The size of California's economy makes a strong argument for selecting it as a target for this sort of policy. Because so much of any product goes to consumers in California, companies are motivated to modify their entire production process to comply with California regulations (Suithivarakom, 2020). States that have public support for climate policy and a political climate that is conducive to introducing new legislation are possible targets for developing a mandate that would be in effect within a single state. For instance, states that are part of the US Climate Alliance may also be good candidates for this policy as participation in the alliance demonstrates the political climate necessary for pro-environmental action (Holland, et al., 2020). Two interview respondents also provide support for a state-level mandate. Consumer expert 4 specifically cited California as an ideal candidate because "companies sending products into California would [have to comply], which would affect their [production] in other states" as well. Wholesaler 2 noted that when a new standard is implemented in a place a company does business, they will change their internal practices across the company because it is more efficient, reducing costs and streamlining production.

Federal labeling mandate

As an alternative to mandating all food distributors to account for carbon, the federal government could mandate a carbon label to be utilized on all food products sold within the US. This mandate would require the quantification of emissions without restricting operations, as would be required by other accounting strategies. Development, implementation, and regulation of this strategy would employ funding and labor of the Food and Drug Administration. As mentioned, the FDA has amended food product labeling requirements in 1994, 2016, and 2020, therefore, this recommendation presents an opportunity to circumvent political contention relating to the adoption of new policies. However, as noted through the interview with Government 4, this policy would require the support of large food related firms to be politically successful. This is due to the resistance for such firms to support legislation that could hinder profit margins, as would occur if firms were responsible for funding their own LCA data collection, and accounting strategies. To gain the financial and political support of these contenders, Wholesaler 1 noted that a strong business case would need to be utilized to prove that the implementation of this policy would result in net financial gain.

Recommendations for the structure of a labeling mandate were also provided through interviews. As noted in the consumer behavior portion of this report, on average, consumers value elements of price and taste over those relating to sustainability. Attention and value are not allocated toward sustainable labeling or purchasing largely because these actions would require additional information and education to adequately understand. For a carbon footprint label to be effective, the information presented must both be standardized and simplified. Consumer Expert 2 noted that the only strategy they found to be effective for changing consumer behavior through their research was a spotlight system. Utilizing colors with embedded symbology to note if a food product has a low, medium, or high carbon footprint, was easy for consumers to understand and use. Advocacy Agency 1 also noted that the public largely understands the notion of carbon neutrality, and that a federally regulated, but voluntary, carbon neutral label could communicate this valuable information in a comprehendible, useful, and even less contentious manner.

Similar to enhanced data regulation, a labeling mandate and regulatory protocol would utilize the government as a leverage for enacting system change. Actors across all sectors of the food system would subsequently quantify their carbon emissions and employ transparency of operations through labeling. This enhanced transparency and availability of food products' carbon footprint information could then be utilized by consumers to enact purchasing power in favor of less carbon intensive products.

Healthy Eating Index and SNAP

Utilizing existing food programs that intersect the federal, state, and local governments such as the Supplemental Nutrition Assistance Program (SNAP) and the Healthy Eating Index, also present substantial opportunities for emissions reduction. As previously discussed, SNAP provides food assistance to low-income families and individuals by subsidizing qualifying food products. While this program largely piggybacks off surpluses, opportunities exist to instead subsidize food products that have reduced carbon footprints. Federal funding would then operate as an incentive for distributors to pressure sectors across the remainder of their food chain to calculate and ultimately reduce their associated emissions. Furthermore, the Healthy Eating index is a USDA program that collaborates with Health and Human Services to establish dietary guidelines as the basis of physician recommendations and standards for meal services, such as those within public schools, retirement homes, homeless shelters, and refugee camps (6). This program aspires to find associations between diet and health outcomes. While the metrics that have been historically utilized have revolved around consumption patterns, there exists space to expand these metrics to those incorporating environmental health measures such as carbon accounting. Emissions reduction could more loosely be applied through this program through a reduction in ultra-processed foods provided and recommended. Such foods, on average, represent higher carbon footprints due to sourcing and processing emissions as transportation represents 6% of emissions and processing represents 4-15 percent (Joseph Poore & Thomas Memecek, 2018).

These recommendations are directly aligned with interview excerpts discussing future projections for the use of carbon accounting and leverages for changing the system to reduce net emissions. Consumer Expert 1 and Retailer 3 both advocated for the utilization of government procurement to increase the salience and demand of sustainable food products. Through this approach, a clear, direct association between public funding investments and public benefit can be drawn, supporting continued investment and influence from the government to other sectors of the food system. Additionally, by both exposing and educating members of the public through such programs, they are more likely to make independent purchasing decisions that reflect sustainable values. Therefore, consumer influence would be utilized as a leverage for influencing action within the food system.

Amending these existing programs mitigates political contention that is often paired with the presentation of new bills. Furthermore, as SNAP is a program funded through the Farm Bill, opportunity for the adoption of new amendments can occur as soon as 2023.

Conclusion

The current US food system is highly industrialized and is a main source of the nation's carbon emissions. While some may argue that the best solutions are to descale and make food systems more localized, there needs to be a short-term solution to address carbon emissions. The purpose of this research was to question whether a federal carbon accounting mandate - a mandate that would require food distributors to calculate their product level emissions - could be an effective strategy for reducing emissions and mitigating climate change. To do this, researchers conducted literature reviews, identified and interviewed stakeholders, analyzed those interviews to identify leverage points, addressed barriers, and proposed alternatives. The sectors interviewed in the research were producers, processors, wholesalers, retailers, consumers experts, data experts, and government officials. Interviews were analyzed based on five core themes: current state of carbon accounting, internal mechanics, adoption of sustainability policies, challenges to adoption, relationships with other sectors, and future projections. These themes were used to create codes and subcodes in order to understand opportunities, barriers and possible leverage points for change. The interviews were used to inform the results and discussions as well as to create a visualization of the food system network. This visualization highlighted the influence of processors and the vulnerability of producers. Upon reviewing this data, researchers recommend that the focus of carbon emissions in the food system should be switched from producers to processors. Processing companies, especially those that are vertically integrated, have the resources to reduce emissions when compared to the resources producers have.

Currently, a federal carbon accounting mandate would not be the best use of time, energy, and resources due to the overwhelming number of barriers to successful passing and implementation. Without an agreed-upon structure to measure emissions, a plan for regulation, and resources to overcome political contention, the mandate would most likely be unsuccessful in Congress and in reducing emissions.

Instead, there are alternatives to policy mandate – that of using life cycle assessment LCA to accomplish emissions reductions in other ways. There are several options for doing this. The first option is to invest in carbon accounting data and increase validity of LCA methodology. The second option is to use the current LCA data for targeted reduction, which is one of the main purposes of conducting LCAs. Third, a policy mandate could be proposed at the state level, particularly within a state that is likely to pass such a proposal and has a large enough economy that it will still be impactful (i.e. California). Fourth, this mandate could be turned into a federal carbon labeling mandate. While the political contention would still be a hurdle, this option is the most feasible with assurance that emissions will decrease due to consumer and investor pressure. Lastly, instead of a separate policy, carbon quantification can be a proposed amendment to an existing policy, such as SNAP or the Healthy Eating Index. Ideally, resources should first be put into standardizing LCA data collection. This would make any passing of a mandate that utilizes LCA data much easier. After this, the recommendation is to amend an existing policy instead of proposing a new one at either the state or federal level.

Appendix A:

Defining important terms:

General Terms

Sectors- Collection of actors and organizations that represent a primary action within the food system

Carbon Equivalent- Carbon dioxide equivalent or CO2e means the number of metric tons of CO2 emissions with the same global warming potential as one metric ton of another greenhouse gas (EPA)

Carbon quantification- Calculating the carbon equivalent emissions of a product throughout its entire life cycle. This includes emissions from the initial resource extraction, through the consumption of the final product.

Carbon accounting - Setting a specific, but changeable goal, for the net emissions represented by all products consumed by an entity. These values are initially calculated through carbon quantification, then used to establish reduction goals for an entity through which it will make decisions for emissions reduction strategies.

Carbon budgeting - the understanding of carbon accounting in order to manage total allotted emissions when given parameters of time and total emissions on an individual, corporate, institutional, national, or global level

Sector Definitions

Government - local, regional, state, and federal governing bodies and officials that have regulating power over US businesses, organizations and populations

Research/ Data Processing - researchers who study Life Cycle Analysis and carbon accounting

Processors - Companies that source ingredients from producers and transform them into individual food products to sell. Includes corporations that have multilateral impacts on the food system, as well as regional food processors that operate as middlemen between producers and wholesalers

Wholesalers- companies that procure food products from processing companies, then resell them to retailers

Consumers- the general US public, food purchasers for eating purposes

Retail/ Procurement - grocery stores, restaurants, and other entities between wholesalers and consumers that facilitate the exchange of money for food

Producers - farms producing raw, unprocessed agricultural products to sell directly to consumers, or to processors

Appendix B: Code Analysis

1. Carbon Accounting

1a Current strategies for emissions reduction

Carbon accounting strategies for emissions reduction was mentioned in 14 excerpts by 11 interviewees across five categories (processors, wholesalers, producers, government, and retail. A wide variety of strategies were mentioned, with the most coming from processors and included carbon neutrality commitments, broad emission reduction goals, and incorporating science-based targets. Two processors said that they do incorporate LCA information, but one said the information was only used internally and not shared beyond the company. Wholesale interviewees talked about internal strategies, including multi-department teams working to develop goals and strategies. Two wholesalers have programs to transition to electric vehicles. The retailer has achieved zero waste in one of their restaurants by partnering with a consulting company and plans to expand this to additional locations.

1b Carbon accounting within current strategies

Carbon accounting within current strategies was mentioned in 10 excerpts by six interviewees across three categories (processors, wholesalers, and Advocacy organizations). One processor said they conducted annual carbon accounting across Scope 1, 2, and 3, with LCA's conducted for a small selection of products. One processor said there was not enough value in product level LCA's because of the resources required to conduct them for tens of thousands of SKUs. One Advocacy Organization manages a database of food system carbon accounting data, including assessments beyond what is available in a basic LCA.

1c Components needed for a carbon accounting mandate to be successful

Components needed for a carbon accounting mandate to be successful were mentioned in 11 excerpts by seven interviewees across five categories (processors, wholesalers, government, producers, and retail. Across sector categories, interviewees noted the need for transparent, verified, and accessible data. Several interviewees also expressed concern in what entity would be responsible for maintaining the data and making sure that it was usable and understandable. Producer 2 stated strongly that "open systems with an open governance structure is a must". Retailer 1 noted that without support from external sources, such as academia or government, small businesses would struggle to comply or make use of carbon accounting data.

1d Comments about the current state of carbon accounting

Comments about the current state of carbon accounting were mentioned in 23 excerpts by 12 interviewees across five categories (Processors, consumer experts, Data Researcher, Advocacy organization, and producers). Consumer expert 3 said "carbon accounting is a really promising first step towards true cost accounting," but other interviewee comments expressed concern

about the current state of carbon accounting. Many interviewees across categories worried about the difficulty of developing good LCA data and recognized that once made there were still limitations to the data and its usefulness. Processor 3 noted that an LCA is "a snapshot," and wondered who would determine when they should be done, and how the decision would be made, Processor 4 adds to this point, noting that the LCA's used by the company are six years old and no longer reflect the current supply chain. Consumer expert 5 brought up the difficulty that LCA data comes from previous seasons, and if decisions are made prior to a growing season because of LCA data, there is no way to make decisions part way through the season based on real time conditions, such as drought. Some interviewees worry that the resource intensive LCA data may take away efforts for other equally, or more important initiatives, with Consumer Expert 5 noting that no matter what, the data points to reducing ruminant meat consumption. Data researcher 2 said that it is "important to recognize that [the food system] is not as straightforward as switching all of our cars over to electric and renewable energy generation," because there are unavoidable GHG emissions associated with agriculture, making goals of sustainability in the food system more nuanced than in other production and consumption systems.

2. Internal Mechanics of sustainability policies

2a Drivers of sustainability

Drivers of sustainability were mentioned in 21 excerpts by 10 interviewees across five categories (processors, government, producers, retail, and wholesalers. The power of CEO's to drive sustainability was explicitly mentioned by Processor 1, Processor 3, Processor 4, Producer 2, Retailer 2, and Wholesaler 2, saying either that sustainability policies happened because the CEO prioritized it, or that sustainability policies would not happen unless the CEO approved of it. Multiple interviewees included the CFO or financial benefits in general as key to implementing sustainability policies, summed in Processor 2's comment that "there has to be a strong business case…if I can make that business case, then I have all the power in the world to push it, get it through, and make it happen." Interviewees more closely related to agricultural production, including all three wholesaler interviewees, predominantly commented on this topic.

2b Implementation of sustainability policies

Implementation of sustainability policies was mentioned in 13 excerpts by eight interviews across five categories (processors, government, Advocacy organizations, retail, and wholesalers). Implementation of sustainability policies vary across interviews, aligning with responses about current strategies for emissions reduction (1a). Emissions tracking, procurement policies, and carbon neutrality plans were mentioned by processors and Advocacy organization 1. Retail 3 saw particular implementation possibilities in food school programs because there is direct link to securing benefits with expenditures of public money. Retail 2 noted that their successful implementation experience was due to the specific nature of the intervention, reducing the likelihood of confusion among participating employees.

2c Motivations for sustainability policies

Motivations were mentioned in 16 excerpts by nine interviewees across six categories (processors, consumer experts, Advocacy organizations, retail, and wholesalers). The three main motivations mentioned across interviews were marketing, financial benefit, meeting customer wants, and providing internal information. Wholesaler 2 attributed recognizing the vulnerability of food systems as a motivator for addressing risks to sustainability in their policies.

2d Lack of sustainability policies

Lack of sustainability policies was not found to be a relevant code.

2e Defining sustainability

Defining sustainability was mentioned in 20 excerpts by 13 interviews across six categories (processors, data researchers, government, producers, retail, and wholesalers). A myriad of efforts in addition to reducing GHG emissions or specifically utilizing carbon accounting were described as important motivators across all six categories. Reducing packaging and food waste, water stewardship, and social equity were all mentioned by multiple interviewees. Additionally, Processor 1 noted that consumers "might care about sustainability but usually it's not as specific as carbon emissions," citing reasoning for addressing multiple sustainability factors.

2f Strategies for sustainability

Strategies for sustainability were mentioned in seven excerpts by six interviewees across four categories (processors, government, Advocacy organizations, and producers). Processor interviews noted the importance of aligning sustainability with financial interests, including incentivizing policies, becoming a BCorp, and trusting that, despite being the origin of environmental problems, "capital markets and capital…are able to solve most of our problems." Advocacy organization 1 has found that developing messaging around carbon neutrality, instead of emissions labeling, is easier for consumers to understand. Government 1 is focused on developing a "hyperlocal" food system, while Producer 2 contrasted US and European efforts with those of China, where the government spearheads vertical integration as a way to achieve sustainability goals.

2g Timescale for internal policies

Timescale for internal policies was mentioned in five excerpts by four interviewees across three categories (processors, Advocacy organizations, and wholesalers). Interviewees were divided, some thinking internal policies could be in place within a few years, and others thinking that a much longer timescale was necessary.

3. Challenges of carbon accounting

3a Internal barriers

Internal barriers were mentioned in 18 excerpts by 11 interviewees across six categories (processors, government, Advocacy organization, producers, retail, and wholesalers). Limits to money, time, internal buy-in, enforcement capacity, scope of influence were noted as internal barriers across categories. Although some categories are significantly different from one another, reported internal barriers did not reflect this difference. Processor 4 described many of these concerns, saying that LCA's are "very expensive, [with] huge data sets and models [that aren't] in the public domain. It's a pretty heavy lift…You have to have the resources internally to manage that and the political will within the company to do it."

3b Sector barriers

Sector barriers were mentioned in 10 excerpts by six interviewees across five categories (processors, data researchers, government, producers, and wholesalers). Processors noted that there is much in the supply chain that is out of their control, limiting their capacity to act in their domain. Producer 3, a commodity farmer, feels that there is constant pressure to expand operations, making farming harder as time goes on. Producer 1, reflecting on barriers for small producers, sees that most assistance and equipment for producers are geared toward commodity farms, leaving few resources to help small producers transition to improved practices. Government 1 also noted this pressure for small farms and saw the biggest barrier within government being that the overarching goal of carbon accounting for citizens is behavior change, and the government is not well equipped to do this. Similar to processors, Wholesale 1 sees their sector as dependent on other sectors for the information, creating a potential problem. Data researcher 2 also pointed out this problem, noting that wholesalers would be reliant on producers to provide them information. Additionally, there is a barrier within the data because it is not "coordinated [in a way] that would require a robust standard and computational structure," opening carbon accounting to discrepancies and inconsistencies.

3c US food system barriers

US food system barriers were mentioned in 29 excerpts by 15 interviewees across eight categories (processors, consumer experts, data researchers, government, Advocacy organizations, producers, retail, and wholesalers). Every category of interviewees mentioned barriers to carbon accounting and sustainability within the US food system. Processors noted that the US is behind the EU in data gathering, analysis, and policy implementation. Wholesaler 2 attributed a problem with accountability to inevitable turnover that happens with upper-level management; if one person sets a goal for 15 years in the future, who will be there to keep the company on track. Distributors currently prioritize order fulfillment and delivery above other goals, which creates a barrier to making decisions based on carbon accounting. All three wholesaler interviewees and Data 1 discuss barriers related to information, whether it is

consumers not understanding carbon data, or retail purchasers overwhelmed by information in portfolio databases. Producer 1, Advocacy organization 2, government 3, and data 3 see challenges to consumers being informed and having agency in their participation with the food system, noting a general disconnection with the food system, accessibility problems and the critique of false choices in the grocery aisles. The majority of comments about US food system barriers relate to the consolidation of corporate agriculture businesses and the disproportionate amount of power these businesses have at the governmental and policy level. The USDA is siloed from agricultural concerns beyond yield, and lobbies and subsidies often shift incentives and priorities away from sustainable practices. According to Data 3, carbon accounting may increase consolidation pressure because compliance will be difficult for small producers and increase the power of large firms to continue to 'reshape regulations that affect nearly every aspect of society to their benefit."

3c-2 consumer behavior

Consumer behavior was mentioned in 18 excerpts by nine interviewees across five categories (processors, consumer experts*^, Advocacy organization, producers, and wholesale). Consumer behavior is viewed as a barrier to effect carbon accounting policies because of their limited understanding of and familiarity with the concept. If consumers do know about carbon accounting, having information about it in the retail space still may not lead to desired behavior change for a variety of reasons. Processor 2 recognizes that decision making happens very quickly, and there is not time to process a large amount of information. There may also be too much information presented. And, as mentioned across categories, food choice is influenced by many different factors including price, flavor, and familiarity, and research shows that these are usually more powerful drivers of choice than information about sustainability. Given these barriers, Processor 3 worries that a "huge amount of effort and energy into something that won't actually change how people make decisions."

3d Political barriers

Political barriers were mentioned in 13 excerpts by 10 interviewees across eight categories (processors, consumer experts, data researchers, government, Advocacy organizations, producers, retail, and wholesalers). Observations about political barriers were spread fairly evenly across categories, although specific concerns varied. Consolidation came up as a political barrier because it increased the political power of the biggest agribusinesses. Interviewees in four categories specifically mentioned the influence of lobbies, specifically livestock and dairy, in shaping policy and regulation in the US. Advocacy organization 2 highlights the career evolution of Secretary Vilsak, the current Secretary of Agriculture under Biden. Vilsak also held this position in the Obama administration, with a period working for the dairy lobby in between his appointments. Retail 3 notes that within the government, the word "sustainability" is still not wholly trusted and "resilient and climate smart are more likely in conversations at the federal level.

3e Data barriers

Data barriers were mentioned in 50 excerpts by 18 interviewees across eight categories (processors, consumer experts, data researchers, government, Advocacy organizations, producers, retail, and wholesalers). Many interviewees described the LCA process as not feasible on the product level because of the expenses required and the prohibitive amount of data process required to assess entire product catalogs from large businesses. These concerns were mentioned by processors, consumer experts, data researchers, Advocacy organizations, and wholesalers. The next set of barriers identified relate to the quality of the data that is currently being collected. Data researcher 2 and government 3 describe the lack of centralized methods to be a concern, while Data 2, Data 3, Producer 2, and Wholesale 2 note that there is extensive standardization in the data, which has effects on the results and can negatively impact accuracy. Producer 2 says that the only way to satisfactorily overcome this is recognizing that "primary data is king" and use that as the ultimate goal of quantification efforts. Wholesale and retail interviewees worry that they do not have access to carbon accounting data on their own and see an uphill struggle to obtain the information from a trusted collaborator.

3f Unintended consequences

Unintended consequences were mentioned in 24 excerpts by 14 interviewees across seven categories (processors, consumer experts, data researchers, government, retail, and wholesalers). The main unintended consequences that were brought up across categories relate to earlier mentioned barriers, including the US food system barriers of the consequences of consolidation. Data researcher 1, Data researcher 3, and Wholesale 3 believe that small farmers and businesses would be negatively impacted by a carbon accounting mandate. Data researcher 3 says this would further contribute to consolidation because "regulations are a really effective way to provide advantages to larger firms…because it has become so difficult to comply with regulations, except at a very large scale." Data researcher 3 sees a possible trade off of other sustainability goals because of the amount of resources carbon accounting requires, coming "at the cost of bigger system level properties that are really difficult to track…. system resilience…When we're just focused on reducing emissions per unit of production, that could be driving us into places that are not ultimately most beneficial for society." Government 3 expressed a similar concern, that a mandate would pull resources from other important efforts. Processor and Wholesale interviewees expressed concern that declaring LCA data would make businesses vulnerable to being accused of greenwashing and possibly litigation because of how complicated correctly developing the data can be. This could also lead to accusations of greenwashing.

3g Legal barriers

Legal barriers were mentioned in seven excerpts by five interviewees across three categories (producers, government, and wholesalers). Putting carbon accounting data on products without a centrally coordinated methodology creates concerns around liability for Processor 1 and

Wholesaler 3. Government 2 and Government 3, working on the municipal level, do not have authority to regulate production or business inventories, limiting their capacity apply carbon accounting data in an impactful way.

3h Communication challenges

Communication challenges were not found to be a relevant code.

4. Relationships

4a Sectors you influence

Sectors you influence were mentioned in 15 excerpts by 10 interviewees across five categories (processors, consumer experts, government, retail, and procurement). These excerpts are operationalized in the network analysis visualization, figure 10.

4b Sectors that influence you

Sectors that influence you were mentioned in 27 excerpts by 13 interviewees across five categories (processors, consumer excerpts, government, retail, and wholesalers). *These excerpts are operationalized in the network analysis visualization, figure 10.*

4c Powerful players

Powerful players were mentioned in 36 excerpts by 18 interviewees across seven categories (processors, consumer experts, data researchers, NGP/Advocacy organizations, producers, retail, and wholesalers). Descriptions of powerful players in the food system followed previous comments about consolidation and multinational agribusinesses. Wal-Mart's supplier criteria were mentioned by two processors as having a significant impact on their practices. Data 2 points to the impact lobbyists for these largest businesses have on regulations, seeing a similar possibility for the development of carbon accounting and reporting as well. Wholesaler 3 notes these companies aren't going away; "you have to figure out how to change them as you aren't going to stop buying from them." Consumer expert 2 sees potential here; "they work with millions of farmers. They feed billions of people every day. If you can impact what they're prioritizing, then your project will have a huge impact on the world." Consumer expert 1 offers a different assessment of power dynamics, seeing distributors and retailers as having the greatest power, creating a bottleneck in the supply chain like an hourglass.

5. Future Projections

5a Impact of a future mandate

Impact of a future mandate was mentioned in 20 excerpts by 14 interviewees across seven categories (processors, consumer experts, data researchers, government, Advocacy organizations, retail, and wholesalers). Possible impacts of a future mandate showed up in all but one interview categories and were generally split between negative and positive impacts.

Multiple interviewees posited that a mandate would have a negative impact on farmers and lower income populations. Retailer 3, informed by previous experience with large scale purchasing criteria, has seen how large companies "learn pretty quickly how to meet program requirements without actually changing what they're doing," as when a baked goods producers modified their recipe to include 51% whole grains, exceeding the new 50% requirement by the barest minimum. On the other hand, processor, consumer expert, and government interviewees saw a potential catalyst for action among business, creating an opportunity for change and likely shifting consumer behavior because of shifting norms and availability of information.

5b Timescale of mandate

Timescale of a mandate was mentioned in seven excerpts by seven interviewees across five categories (processors, data researchers, government, Advocacy organizations, and producers). Processor 2 and Government 3 were optimistic that they could implement carbon accounting in a few years' time. However, the majority of interviewees who had an opinion on the timescale of a mandate were not optimistic, Processor 3 saying it is "unlikely to happen." Producer 2 thought that it was possible but, given the data limitations, a complete carbon accounting taking all factors into account would not be possible within the next 30 years.

5c Requirements of mandate

Requirements of a mandate were mentioned in 20 excerpts by 12 interviewees across seven categories (processors, consumer expert, data researcher, government, Advocacy organization, producers, and wholesaler. At least one interviewee from five categories cited recognized standards and a verification program as the requirement priorities for a carbon accounting mandate. Several interviewees also advocated for the mandate to be tailored to the size of a business, possibly with some sort of financial assistance provided as well. Several categories also underscore the importance of the implementation of a carbon accounting mandate being user friendly and increase participation and baseline knowledge of consumers.

5d Pathway to mandate

Pathway to a mandate was mentioned in three excerpts by two interviewees across two categories) .

6. Possible strategies

6a Leverage points

Leverage points were mentioned in 54 excerpts by 20 interviewees across eight categories. Leverage points focused on the ways respondents saw carbon accounting data to have an impact on the food system, although not necessarily through a federal policy. These leverage points are discussed in *Alternative leverages for intervention.*

6b Theory of change

Theory of change is mentioned in 37 excerpts by 14 interviewees across seven categories. Across sectors, respondents had many different conceptualizations about how change happens within the food system. Some of them, such as a lack of education and information, or the idea of innovators leading the way, are common in behavior change research. There were three main scopes through which respondents saw change occurring: at the personal level, at the business level, and through marketing. Consumer Expert 3 noted that over time, people "will incorporate the information and shift their behaviors" and that policy changes would likely follow behavior change. Wholesaler 3 exemplified the belief that motivated business would lead the way, "moving forward without federal action on carbon emissions." Multiple respondents in different sectors saw the powerful role that marketing can have in setting purchasing behavior, recalling the number of interviews that noted marketing as a main motivator for companies to make statements about sustainability policies to the public.

7. Wholesale/Distributors

Wholesale/Distributors was not found to be a significant code, making up less than 1% of total excerpts.

8. Research

Research was not found to be a relevant code.

9. Government

9a Federal

Federal government was not found to be a significant code, making up less than 1% of total excerpts.

9b State

State government was not found to be a significant code, making up less than 1% of total excerpts.

9c Local

Local government was mentioned in nine excerpts by four interviewees across two categories (consumer researchers and government). Consumer expert 4 noted potential on the municipal level for emission reduction efforts with procurement policies, but likely not involving labeling. The general consensus among government interviewees was that a carbon accounting mandate was not feasible on the municipal level. However, they did feel that there were other, less direct ways for their sector to have an impact on community emissions.

10. Consumers

This code was relocated to 3c-2

11. Retail

Retail was not found to be a significant code, making up less than 1% of total excerpts.

12. Producers

Producers was not found to be a significant code, making up less than 1% of total excerpts.

13. NGO’s

NGO’s was not found to be a significant code.

14. Justice and equity

Justice and equity was mentioned in 18 excerpts by nine interviewees across five categories (processors, consumer experts, data researchers, government, and wholesalers). Although only about a third of respondents touched on these issues, they detailed many concerns, providing a similar number of coded excerpts as other topics covered by many more interviews. The three main themes that arose in the excerpts were concerns that: increased costs would be a burden on low income families, small and medium-scale producers do not have the resources to comply with additional regulations, and that other important sustainability factors such as worker rights are not included in carbon accounting processes.

15. Global

Global factors were not found to be a significant code, making up less than 1% of total excerpts.

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