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**Is it hot in here or is it your food choices? Examining the carbon footprint of U.S. household food spending and opportunities for emission mitigation strategies through changes in food expenditures**

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## **1. BACKGROUND AND INTRODUCTION**

Food production is necessary to sustain human life. However, the outputs of the global food system are not limited to food products. The processes in the food supply chain including agricultural production, food manufacturing, transportation, and retailing produce outputs that are harmful to the environment, specifically greenhouse gas (GHG) emissions. GHG emissions are contributing to climate change which threatens the well-being of ecosystems and societies across the globe and reductions are urgently needed (IPCC 2014).

Consumers can make an immediate and sizeable contribution to global GHG emission mitigation efforts by altering their food choices. Food presents a unique opportunity for emission mitigation for three main reasons. First, some foods are relatively more carbon intensive to produce than others. Beef, in particular, is a carbon intensive food, as are other animal products such as cheese and dairy (Garnett 2009). Plant based foods have been found to cause much fewer GHG emissions (Garnett 2011). Second, food accounts for a relatively large share of household GHG emissions; up to 30% according to some estimates (Jones and Kammen 2011; Kim and Neff 2009). Third, households can in theory alter their food choices in a relatively short time frame (i.e. in a day or week), which could result in immediate GHG emission reductions. However, reducing diet-related GHG emissions may impact nutrition and food costs and the tradeoff herein must be examined. Understanding these tradeoffs is especially important for low income and food insecure households who face limited food budgets and who are at particular risk of nutritional deficits.

The better understand the relationship between GHG emissions of diets, food costs, and nutrition and opportunities for GHG emission mitigation through changes in U.S. diets the present study has three objectives. First, we create a new estimate of the average per capita GHG emissions of U.S. household diets based on new household-level food expenditure data from the U.S. Department of Agriculture Economic Research Service (USDA ERS) Food Acquisition and Purchase Survey (FoodAPS) and show how GHG emissions vary across household socioeconomic and demographic factors. FoodAPS is the first nationally representative survey to collect item-level food purchase and acquisition data, household sociodemographics, nutritional quality of foods, and information about the food retail environment from non-institutionalized households in the continental U.S. Second, we show the source of these emissions across the food system production and manufacturing industries and supply chain stages (i.e. production, manufacturing, wholesaling, transportation, retailing, and restaurants). Third, we identify food-related emission mitigation strategies for U.S. households that do not compromise food budgets or nutrition.

To achieve the first objective we quantify the carbon footprint of actual U.S. household food purchases and acquisitions from FoodAPS using an Economic Input-Output Life Cycle Assessment (EIO-LCA) model and compare our estimates to previous studies. The comprehensive nature of FoodAPS allows us to obtain a more detailed and accurate understanding of the GHG intensity of actual diets. Its use also allows us to investigate the association between GHG emissions, nutrition, food costs, and household characteristics. To our knowledge this is the first study of its kind to use an EIO-LCA model to estimate GHG emissions of detailed U.S. food expenditure combined with comprehensive data on household

characteristics. We believe our analysis and results provide for the most accurate understanding of GHG emissions resulting from U.S. diets to date.

Up to now only a few studies have quantified the carbon footprint of U.S. diets and significant uncertainty exists in these estimates. These uncertainties need to be resolved and an up to date and more accurate GHG emissions estimate of U.S. diets is needed for developing mitigation strategies aimed at consumers and for institutional and governmental policies aimed at reducing GHG emissions. Previous studies have relied on top-down approaches using aggregate dietary or expenditure data to estimate GHG emissions of U.S. diets and food choices. For example, Weber and Matthews (2008) used Bureau of Economic Analysis (BEA) Personal Consumption Expenditure (PCE) data to estimate the carbon footprint of average U.S. household food expenditures. They found that average U.S. household food expenditures accounted for 8.1 metric tons (mt) of carbon dioxide equivalents (CO<sub>2</sub>e) per year (Weber and Matthews, 2008). This study was mostly focused on examining the GHG emissions resulting from transportation in the food supply chain and so it did not conduct a detailed analysis of the contribution of different dietary patterns or household types to diet-related GHG emissions. In addition, PCE data are aggregated nationally and so this implicitly assumes a uniform food expenditure profile for all U.S. households.

More recently, a 2014 study using aggregate U.S. Department of Agriculture Loss-Adjusted Food Availability data (LAFA) found that the average omnivorous diet based on the Dietary Guidelines for Americans (DGA) results in 3.6 mt CO<sub>2</sub>e per capita per year (Heller and Keoleian, 2014). However, the use of food supply data such as LAFA to calculate GHG

emissions has some drawbacks. First, using LAFA to estimate GHG emissions does not allow for the examination of variation in GHG emissions across different diets or socioeconomic and demographic groups. These top-down approaches used in previous studies (i.e. Weber and Matthews (2008) and Heller and Keoleian (2014)) limit our ability to more fully understand how different dietary patterns or households contribute to GHG emissions resulting from food system activities. By using FoodAPS household-level expenditure data we can obtain a new estimate of the GHG emissions of U.S. household diets using a bottom-up approach. With this approach we can explore the distribution of GHG emissions of food choices across different U.S. households and the detailed patterns in GHG emissions across various food spending behaviors. The results of this more detailed analysis can help better target emissions mitigation strategies by identifying the most GHG emission intensive components of U.S. food choices and the households who consume them.

One U.S. based study conducted in 2011 did attempt a more bottom-up analysis using food expenditure data from the Consumer Expenditure Survey (CES) collected by the U.S. Bureau of Labor Statistics. It found that average household food expenditures result in 5 to 7 mt CO<sub>2</sub>e per year (Jones and Kammen, 2011). This study improves upon previous attempts to understand the variation in the GHG emissions of diets across U.S. households, but it was not focused on assessing the variation in GHG emissions across specific food types purchased by households. Instead, it grouped foods into only 5 categories (meat, dairy, grain and bakery, fruit and vegetables, and other foods). So while it did explore how GHG emissions vary across a limited set of household characteristics it did not explore in detail which specific foods contribute to the GHG emissions of U.S. diets. We correct for this food aggregation issue by conducting a detailed

analysis of the specific foods that contribute to GHG emissions of diets using a bottom-up approach with household level expenditure data in FoodAPS.

Some European studies have used the bottom-up approach to estimate GHG emissions using self-reported food intake data (Vieux et al. 2013; Drewnowski et al. 2015). These studies address the data aggregation issue by which the aforementioned top-down studies are limited. However, self-reported food intake data collected in surveys can suffer from self-report bias. That is, survey participants may underreport their intakes, which in this research context would underestimate GHG emissions (Heller and Keoleian 2014). More importantly self-reported food intake surveys also do not capture the amount of food that is purchased but not consumed. This wasted food should be accounted for both because of the GHG emissions produced from its production and the additional GHG emissions resulting from its decomposition in landfills (Garnett 2011). Our use of food expenditure data to calculate GHG emissions of U.S. household diets includes all foods purchased so implicitly captures the amount of food household's waste.

FoodAPS reports on a variety of household characteristics which allows us to more fully assess GHG emissions of diets at a more disaggregated level than previous studies. Understanding how emissions vary across household characteristics, especially on the basis of income and food spending, can be used to ensure that more sustainable diets, such as those with lower GHG emissions, are accessible and affordable to all types of households. Understanding the relationship between sustainability of diets, accessibility, and affordability was one of the key recommendations for future research needs of the 2015 Dietary Guidelines Advisory Committee report (U.S. Department of Health and Human Services, 2015). Currently no study has

comprehensively examined the association between GHG emissions of U.S. diets or expenditures and household or individual characteristics. Jones and Kammen (2011) did examine how diet-related GHG emissions vary according to household characteristics and found that expenditures and, therefore resulting emissions, on food were essentially identical across income quintiles controlling for household size. However, the authors did not conduct further analysis on other characteristics to explain the observed variability in food related GHG emissions across households. No other study to date in the U.S. has conducted such an analysis to our knowledge.

Some research in other countries has assessed how GHG emissions vary across household and individual characteristics. Studies in Europe have found that household and lifestyle factors explain a significant degree of the variability in GHG emissions resulting from consumption of goods and services at the household level (Baiocchi, Minx, and Hubacek 2010). Research in the United Kingdom, for example, found that GHG emissions were positively associated with income but negatively associated with education. A study in Germany found that male diets had a greater contribution to emissions than female diets even after adjusting for differences in total energy needs (Wiedenhofer, Lenzen, and Steinberger 2013). A multi-country analysis of the GHG requirements of household consumption found that emissions vary significantly across sociodemographic groups (Lenzen et al. 2006). Characterizing the association between household and individual characteristics and dietary GHG emissions is important for developing and targeting both policies and behavioral interventions to encourage dietary changes to mitigate emissions. This information can also be used to understand the burden of potential future carbon pricing schemes on different types of households and consumers.



The third objective of this paper is to identify household-level GHG emission mitigation strategies that do not adversely affect household food costs or nutritional quality.

Recommendations to enhance the sustainability of diets in the U.S. must be made in the context of both food security and nutrition. This is because both food insecurity and poor nutritional quality of diets are major public health concerns in the U.S. Approximately 14% of U.S. households are considered food insecure according to the most recent measure of food insecurity by U.S. Department of Commerce Census Bureau Current Population Survey Food Security Supplement (Coleman-Jensen et al. 2015). At the same time, approximately two-thirds of U.S. adults are overweight or obese (Center for Disease Control and Prevention (CDC) 2016). We therefore conclude our analysis with dietary scenarios available to U.S. households that will lower dietary GHG emissions while maintaining food security and nutritional adequacy.

As mentioned earlier we use EIO-LCA to calculate GHG emissions of household food expenditures. LCA is defined as the “compilation and evaluation of the inputs, outputs, and the potential impacts of a product system through its life cycle”, according to the International Organization for Standardization (Guinée et al. 2011). EIO-LCA relies on input-output (IO) analysis, or inter-industry analysis, an analytical method developed by Wassily Leontief in the late 1930s to examine the flows of economic activity in an economy (Miller and Blair 2009). In the 1970s, Leontief further developed the model of economic activity to include a theory for assessing the environmental impacts of the economic flows that occur in an economy and between industries (Carnegie Mellon Green Design Institute 2008).

We believe this tool is excellent for estimating the GHG emissions of food expenditures for three reasons. First, as noted by Weber and Matthews (2008), EIO-LCA is particularly well-suited to estimate emissions for a large bundle of goods. The alternative approach to estimate the carbon footprint of whole diets is to assemble a list of Process-based Life Cycle Assessment (PLCA) estimates of the GHG emissions of specific types of foods and beverages. One problem with this approach is that individual PLCA studies do not have consistent system boundaries and as such are subject to cutoff error (Weber and Matthews 2008). In LCAs system boundaries determine the range of the supply chain over which GHG emissions are estimated. These system boundaries of PLCA studies are subjective to author discretion and not always consistent across studies. EIO-LCA, on the other hand, has consistent system boundaries determined by the economic model itself that encompasses the bounds of the country's entire economy (i.e. cradle to retail sector). Secondly, the number of PLCA studies of U.S. food and agricultural products are limited and so using them to determine the GHG emissions of U.S. diets is limited by how many products have been analyzed. Heller and Keoleian (2014) for example, assemble a list of >100 PLCA studies but many of these are not based on U.S. food production systems. Third, individual PLCA studies may use different methods to account for GHG emissions in the production of foods and so aggregating studies may cause biased GHG emission estimates of diets.

While EIO-LCA is a powerful tool for quantifying the environmental impacts of economic activity, it has shortcomings. One of the main issues with using EIO-LCA to estimate environmental impacts, such as GHG emissions, is the aggregation present in these models (Lenzen 2011). That is, GHG emissions or other environmental impacts for specific products at

final demand may be incorrectly specified by these models because impacts are calculated at the industry level and not at the product level. Using EIO-LCA GHG emissions intensities are determined at the industry level and are defined by the Bureau of Economic Analysis (BEA) industry definitions. However, the production functions of the various firms producing goods within each of these industries may be different, resulting in heterogeneous environmental impacts. In some cases the differences in environmental impacts or production functions across firms within industries may be small. In other instances, intra-industry GHG emission intensity or production function differences may be relatively large. There will always be some issue of aggregation bias in these models and that is a major critique of EIO-LCA as a method for estimating environmental impacts of products. However, given the limitations of PLCA for evaluating many food types, we believe it is the best tool for estimating emissions of the broad range of U.S. household food expenditures contained in FoodAPS.

## **2. DATA AND METHODS**

### ***2.1 U.S. household food expenditure data***

Our consumer food expenditure and acquisition data comes from USDA's FoodAPS. The sample includes 4,826 households from four strata: household receiving Supplemental Nutrition Assistance Program (SNAP) benefits (n=1,581), non-SNAP households with income <100% of the U.S. federal poverty threshold (NS <100% FPT) (n=434), non-SNAP households with income 100%-185% of FPT (NS 100-185% FPT, n=878), and non-SNAP households with income >185% of FPT (NS 185% FPT, n=1,933) (USDA ERS 2016).

Households were asked to record all food acquisitions and purchases for all household members for a 7-day period between April 2012 and January 2013. Adults were responsible for helping to

record the away-from-home acquisitions made by children between the ages of 11 and 17. For foods purchased for at-home (FAH) consumption, household members were given a reporting booklet with barcodes to scan and record items. Households were also instructed to save receipts and document any food purchases and acquisitions, including when a household member received free items. Receipts were the primary method by which food away from home (FAFH) purchases were reported and documented. Phone calls to the reporting agency were also used as a method for households to report foods purchased or acquired during the survey period. The household's Primary Respondent (PR) was interviewed at the beginning and end of the survey to answer questions about household sociodemographics, household expenses, nutritional knowledge, vehicle usage and ownership, and health status. Households received a cash incentive for participating in the survey.

## ***2.2 Economic Input-Output Life Cycle Assessment for estimating GHG emissions of food expenditures***

We use EIO-LCA to estimate the GHG emissions of FoodAPS household expenditures on FAH and FAFH items. In EIO-LCA the relationship between the flow of goods and services between industries and final demand by consumers of goods and services in the economy is represented by the following equation:

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{Y} \quad (1)$$

where  $\mathbf{X}$  is an  $n$  by 1 vector of the total output in dollars produced by  $n$  industries in the economy (see Appendix B for a full list of industries in the U.S. Input-Output (IO) models constructed and published by the Department of Commerce, BEA),  $\mathbf{I}$  is an  $n$  by  $n$  identity matrix,  $\mathbf{A}$  is an  $n$  by  $n$  direct requirements matrix (also known as the technology matrix, also in dollars).  $\mathbf{A}$  shows that relationship between industry inputs and outputs as the output of industry  $i$  required to produce a

dollar's worth of output from industry  $j$  (Carnegie Mellon University Green Design Institute, 2008). In this way  $\mathbf{A}$  provides information on the production functions for each industry in the U.S. economy.  $\mathbf{Y}$  is an  $n$  by 1 vector of final demand of goods and services produced by each of the  $n$  industries, also reported in dollars.

This model is appended with environmental impacts data to assess the environmental outputs of both final demand in  $\mathbf{Y}$ , inter-industry flows in  $\mathbf{A}$ , and total output in  $\mathbf{X}$ . These environmental impacts are determined by the following equation:

$$\mathbf{B} = \mathbf{R}\mathbf{X} = \mathbf{R}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{Y} \quad (2)$$

where  $\mathbf{R}$  is an  $n$  by  $l$  vector representing the direct environmental impact per dollar of each of the  $i$  industries in the economy and  $\mathbf{B}$  is an  $n$  by 1 vector representing both the direct and indirect environmental impact per dollar for industries in the economy. The elements on the diagonal of both  $\mathbf{R}$  and  $\mathbf{B}$  contain the environmental impact per dollar and the rest of these matrix elements are zeroes.  $\mathbf{R}$  and  $\mathbf{B}$  can represent any type of environmental impact per dollar, including but not limited to GHG emissions. For this study the elements on the vectors  $\mathbf{R}$  and  $\mathbf{B}$  are in kilograms of carbon dioxide equivalents per dollar (kg CO<sub>2</sub>e/\$). We call these diagonal elements of  $\mathbf{R}$  and  $\mathbf{B}$  GHG Emission Intensity Factors (EIFs) in this paper.

For this study the economic input-output data in  $\mathbf{X}$ ,  $\mathbf{Y}$ , and  $\mathbf{A}$  are derived from BEA which provides detailed input-output tables every seven years, the most recent of which is from 2007.

The BEA 2007 IO tables are used to calculate the EIFs used in this study (US Department of Commerce BEA, 2014). These IO tables contain economic data on 392 industries in the U.S. economy, hence the dimensions of each matrix in equations 1 and 2 above are as follows: A and I are  $392 \times 392$  and R, B, and Y are  $392 \times 1$ . Twenty-nine of these 392 industries are specific to the agricultural and food and beverage manufacturing industries and of key interest to this study.

The **B** vector for the U.S. IO model represents the EIFs of all of the 392 industries in the economy. Twenty-nine of the 392 industries represent agricultural and food/beverage manufacturing activities. These 29 industries and their EIFs are listed in Table 1. We assume that each food or beverage product purchased by a household in FoodAPS was produced by one of these 29 industries. How we determined the appropriate production industry for each item purchased by FoodAPS households was based on definitions of industries provided by BEA and descriptions of each item provided for in the FoodAPS database. Appendix A lists the specific types of food products produced by each of the agricultural and food/beverage manufacturing industries in the BEA IO model. Appendix A guided the process of mapping each item purchased by FoodAPS households into its most appropriate agricultural or production/manufacturing industry. Full details of the mapping process can be found in section 2.5 of this paper.



**Table 1. Producing/manufacturing industries and EIFs (in kg CO<sub>2</sub>e/\$), in descending order for EIF value**

| <b>Production/manufacturing industry</b> | <b>kg CO<sub>2</sub>e/2012-2013\$</b> |
|--|---------------------------------------|
| Flours and rice                          | 0.5457                                |
| Dry, condensed, and evaporated dairy     | 0.5425                                |
| Cheese                                   | 0.5213                                |
| Poultry                                  | 0.5081                                |
| Milk and butter                          | 0.5001                                |
| Soft drinks, bottled water, and ice      | 0.4921                                |
| Frozen foods                             | 0.4816                                |
| All other foods                          | 0.4592                                |
| Canned, dried, and pickled foods         | 0.4475                                |
| Seasonings and dressings                 | 0.4468                                |
| Eggs                                     | 0.4460                                |
| Fats and oils                            | 0.4457                                |
| Ice cream and frozen desserts            | 0.4262                                |
| Cookies, crackers, pastas, and tortillas | 0.4174                                |
| Beef, pork, and other red meat           | 0.3947                                |
| Beer                                     | 0.3892                                |
| Wine                                     | 0.3860                                |
| Coffee and tea                           | 0.3835                                |
| Breakfast cereals                        | 0.3826                                |
| Sugar and confectionery products         | 0.3820                                |
| Vegetables and melons                    | 0.3695                                |
| Bread and bakery products                | 0.3601                                |
| Soy products                             | 0.3530                                |
| Salty snack foods                        | 0.3466                                |
| Seafood products                         | 0.3324                                |
| Fruits and tree nuts                     | 0.2889                                |
| Spirits                                  | 0.2469                                |

We calculate GHG emissions at the production/manufacturing stage in the supply chain by mapping each item to its respective production/manufacturing industry, the details of which are discussed in detail later. Then, we calculate the post-production /manufacturing GHG emissions resulting from wholesale, transportation, and retail (including restaurant) activities using BEA data on the marginal value of these activities to each dollar of consumer expenditure. The GHG



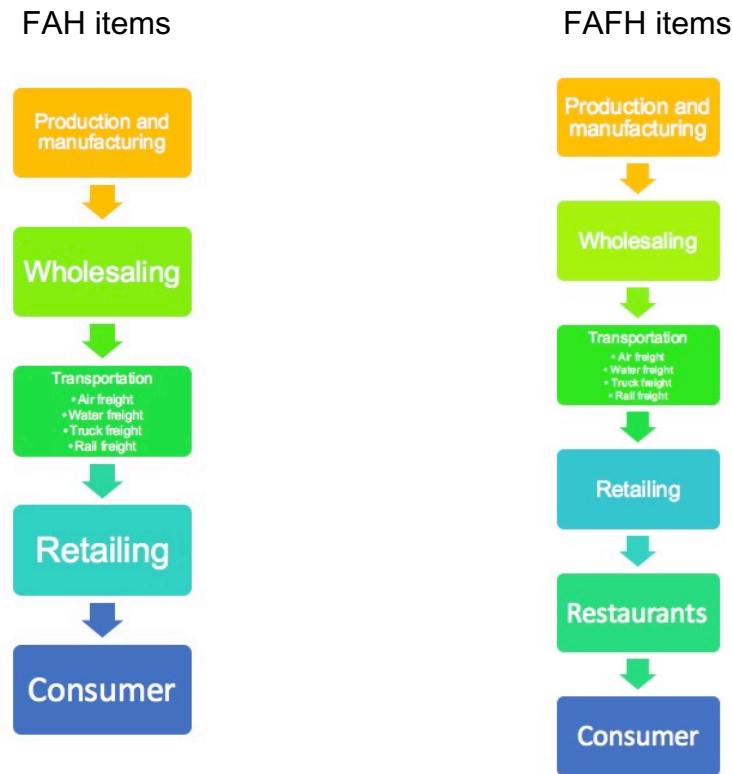
emissions from wholesale, transportation, and retail activities are specific to both the item's production industry and the retail or restaurant industry from which an item was purchased by a consumer. In the 2007 BEA IO tables restaurant and retail level industries include full service restaurants, limited service restaurants, other food and drinking places, food and beverage stores, general merchandise stores (which sell food products), and other retailers that sell food.

To calculate the GHG emissions at each stage in the food supply chain using the EIFs for each production/manufacturing industry for the items purchased by FoodAPS households we rely on the methodology in Jones and Kammen (2011) and in Weber and Matthews (2008) supplementary materials, and which is standard across the EIO-LCA literature. This method requires decomposing a FoodAPS household's expenditure on an item and determining the fraction of the expenditure that is received by actors in the different stages of the supply chain for an item. The stages in the supply chain are defined by BEA IO industries. For FAH items these industries include the: production/manufacturing industry to which the FAH item is assigned (as listed in Table 1); wholesalers; transportation industries (including truck transportation, rail freight transportation, ship transportation via waterways and oceans, and transportation by airplane); and the retailer from which the item was purchased, which is either a food and beverage store, a general merchandise store, or another type of retail store where consumers may purchase food products. For FAFH items the stages in the supply chain include the production/manufacturing industry to which the FAFH item (or, for mixed dishes, each component of the FAFH item) is assigned (see Table 1); wholesalers, transportation industries (including truck transportation, rail freight transportation, ship transportation via waterways and oceans, and transportation by airplane), and the restaurant or food service operation from which

the item was purchased, which is either a full service service restaurant, limited service restaurant, or other food and drinking places such as a bar, caterer, food truck, or truck stop.

Figure 1 below provides an illustration of these different stages in the food supply chain for FAH items and FAFH items.

**Figure 1. Stages of the food supply chain for FAH and FAFH items based on BEA IO model**



The industry-specific average fraction of the cost of each item that is received by each stage in the supply chain is reported in the BEA margins tables for 2007, which accompany the BEA IO tables for the same year. These fractions, or “margins” as they are called in BEA parlance, are both production/manufacturing industry specific and specific to the type of retail or restaurant establishment from which an item is purchased by a FoodAPS household. An example of how we use the production/manufacturing industry, wholesale, transportation, retail, and restaurant

specific margins to allocate the fraction of an expenditure to each supply chain stage is illustrated in Table 2. Suppose a FoodAPS household buys chicken fingers at a limited service restaurant and the item costs \$5.99. Table 2 shows how the \$5.99 spent on the chicken fingers is allocated to each supply chain stage based on the 2007 BEA margins for the production/manufacturing industry (i.e. poultry processors) and the retail or restaurant establishment from which the chicken was purchased.

**Table 2. Example of how we allocate the fraction of a consumer expenditure to each industry in an items supply chain.**

| <b>Supply chain stage</b> | <b>Poultry processing industry margins for limited service restaurant</b> | <b>Amount of FoodAPS household expenditure assigned to each supply chain stage (\$)</b> |
|---------------------------|---|---|
| Producer                  | 0.48  | 2.88  |
| Wholesaler                | 0.14  | 0.85  |
| Rail transport            | 0.01  | 0.03  |
| Truck transport           | 0.01  | 0.07  |
| Water transport           | 0.001   | 0.001   |
| Air transport             | 0.001   | 0.001   |
| Retailer                  | 0.21  | 1.28  |
| Restaurant                | 0.15  | 0.88  |
| <b>Total</b>              | <b>*1.000</b>   | <b>5.99</b>   |

As illustrated in the example in Table2 FAFH items purchased in restaurants pass through an additional supply chain stage, the restaurant industry, prior to consumer point of purchase. The marginal value for restaurants is not provided for in the 2007 BEA margin files and we estimate it ourselves. It is calculated from the economic activity of the value that restaurants add to raw food commodities and other materials needed to produce meals for their customers. Therefore we obtain the restaurant margins by summing the total purchased value of all food commodities by each of the three restaurant types (full service, limited service, or other food and drinking places) and dividing by the purchaser value of restaurants to consumers. This computation can be expressed by equation 3 below:

$$\text{margin restaurant}_j = \frac{1 - \sum_{i=1}^n \text{food commodity}_{i,j}}{\text{consumer value restaurant}_j} \quad (3)$$

Where  $\text{margin restaurant}_j$  represents the margin for the  $j$  restaurant type (i.e. full service, limited service, or other food and drinking places), the numerator is one minus the sum of the value of the all food commodities purchased by restaurant  $j$  and the denominator is the total value of purchases made by consumers for each  $j$  restaurant type.

Next, the fractions assigned to each supply chain stage are then multiplied by the industry specific EIFs to obtain GHG emissions from each activity in the supply chain for each item purchased. Finally, the sum of these products equals total GHG emissions (in kg CO<sub>2</sub>e) for a item. This calculation can be summarized by equation (4) where GHG emissions for each item  $i$  (either FAH or FAFH) are calculated as:

$$\begin{aligned} \text{GHGE}_i = & \frac{\text{producer value}_j}{\text{purchaser value}_j(\text{pv}_j)} \times \text{consumer expenditure}_i (\text{CE}_i) \times \text{EIF}_{\text{prod},j} + \\ & \frac{\text{wholesale value}_j}{\text{pv}_j} \times (\text{CE}_i) \times \text{EIF}_{\text{wholesale}} + \\ & \frac{\text{rail transport value}_j}{\text{pv}_j} \times (\text{CE}_i) \times \text{EIF}_{\text{rail}} + \\ & \frac{\text{water transport value}_j}{\text{pv}_j} \times (\text{CE}_i) \times \text{EIF}_{\text{water}} + \\ & \frac{\text{air transport value}_j}{\text{pv}_j} \times (\text{CE}_i) \times \text{EIF}_{\text{air}} + \\ & \frac{\text{truck transport value}_j}{\text{pv}_j} \times (\text{CE}_i) \times \text{EIF}_{\text{truck}} + \\ & \frac{\text{retail value}_j}{\text{pv}_j} \times (\text{CE}_i) \times \text{EIF}_{\text{retail}} + \\ & \frac{\text{restaurant margin}_j}{\text{pv}_j} \times (\text{CE}_i) \times \text{EIF}_{\text{restaurant}} \end{aligned} \quad (4)$$

where purchaser value  $j$  ( $pv_j$ ) is equal to the sum of the producer, rail, truck, water, air, wholesale, retail, and restaurant value for each  $i$  item assigned to production/manufacturing industry  $j$ . The cost of item  $i$  (either a FAFH or FAH item) is represented by the variable consumer expenditure  $i$  ( $CE_i$ ) and  $EIF_j$  represents the EIF for production/manufacturing industry  $j$  or the post-production/manufacturing industries in the supply chain, including wholesale, rail transport, water transport, air transport, truck transport, retail, and restaurants. For FAH items the term in equation 4 representing restaurants will be zero since these items are not purchased in restaurants. At the production/manufacturing level the EIFs for the producing/manufacturing industries are used (see Table 1). The EIFs for each of the post-production/manufacturing industries in equation 4 is listed in Table 3 below.

**Table 3. Post production/manufacturing industries and EIFs in average 2012/2013 dollars**

| <b>Industry</b>                | <b>kg CO<sub>2</sub>e/\$</b> |
|--------------------------------|------------------------------|
| Wholesale                      | 0.0681                       |
| Transportation                 |                              |
| Truck                          | 0.9487                       |
| Water                          | 1.1016                       |
| Rail                           | 0.8027                       |
| Air                            | 0.8949                       |
| Food and beverage stores       | 0.2104                       |
| Full service restaurants       | 0.1291                       |
| Limited service restaurants    | 0.1276                       |
| Other food and drinking places | 0.1763                       |

Note that the last year BEA published the transportation by mode (i.e. truck, water, rail, and air) margins data was in 2002 alongside the IO table of the same year. For 2007, BEA only released transportation margins in aggregate. As a result, we calculate the transportation by mode margins for this study using the proportion of transportation by mode used for each of the 29

production/manufacturing industries of interest from the 2002 BEA IO model. We therefore make the assumption that the mix of transportation modes used to bring food to consumers has not changed since 2002.

### ***2.3 Accounting for imported and exported products***

BEA IO tables represent the flows of economic activity in the U.S. economy, accounting for imports used by production/manufacturing industries as well the output that these industries export to other countries. For the purposes of this study we assume that the environmental impacts of imported products classified into the 29 production/manufacturing industries of importance to this study are the same as their domestic versions. In addition, the GHG emissions caused by the production of exported goods by these industries are included in matrix **X** and thus in our GHG EIFs. However, only a small share (<4% on average) of the output of each of the 29 production/manufacturing industries of interest in this study is a net exporter (US Department of Commerce 2014). Thus, we believe our GHG EIFs would not be affected significantly by accounting for net exports by these industries. But, we do not account for second tier exports of the products made by industries that supply inputs to the 29 production/manufacturing industries of focus in this study. However, we believe that accounting for these second tier exports would not affect our EIFs significantly and we therefore we exclude their value from the calculation of our EIFs.

### ***2.4 Constructing Emissions Intensity Factors (EIFs)***

The GHG emissions matrix **B** used in this study, showing GHG emissions per unit of production from each industry, comes from the Eco-LCA tool constructed by the Center for Resilience at The Ohio State University. The current Eco-LCA data on GHG emissions from U.S. economic

activity at the website listed above match data in the 2002 BEA IO tables. However, the Center for Resilience has updated this tool to reflect the 2007 BEA IO tables but these newer data are not currently available publicly. The Center for Resilience released an advanced copy of these data to the authors of this paper and it is these data that are used to construct the diagonal elements of the **R** matrix and for construction of our EIFs for each of the 29 food production/manufacturing industries. Details of the accounting of GHG emissions by the Center for Resilience at The Ohio State University can be found at their website (<http://www.resilience.ohio.edu>) and in Bakshi and Singh (2014). In order to match the diagonal elements of **B**, which are in 2007 dollars, to the FoodAPS expenditure data, which are in 2012-2013 dollars, we use an industry-specific price index published by the BEA (U.S. Department of Commerce, 2014). These indices are listed in Appendix C. The EIFs listed in Tables 1 and 3 are already adjusted for inflation using these indices.

### ***2.5 Mapping FoodAPS items to BEA IO production/manufacturing industries***

In order to calculate GHG emissions for each FAH and FAFH item purchased by FoodAPS households each item was mapped into one of the 29 production/manufacturing industries using two different methods. The details of these two mapping processes are outlined in this section.

#### **FAH items**

FAH items consist of items purchased at supermarkets, grocery stores, super stores, specialty food stores, farmers' markets, food bank/pantries, and other retail food stores. A total of 155,958 FAH items were purchased by FoodAPS households. The average supermarket carries 42,214 items (Food Marketing Institute, 2014) and for the purposes of this study each of these items must be classified into one of the 29 production/manufacturing industries listed in Table 1 in order to estimate GHG emissions over each item's life cycle.

For FAH items we classify each into its respective production/manufacturing industry using the USDA Food and Nutrient Database for Dietary Studies (FNDDS) foodcodes and descriptions (USDA Agricultural Research Service 2016). The FNDDS database contains thousands of food and beverage items purchased in the U.S., and each item is assigned a unique eight-digit code. FoodAPS households purchased 3,112 unique FAH items from the FNDDS database. Each FNDDS foodcode also contains information about the nutrients (i.e. fat, vitamin d, iron) and food components (i.e. meat, dairy, vegetables, fruits, and so on) that the item contains.

The number of digits in the FNDDS foodcode needed to assign FAH items to the appropriate production industry depended on the item's respective food group (i.e. meat, dairy, poultry, vegetables, fruits) and the processing it had undergone prior to the point of purchase (i.e. fresh, frozen, canned, dried, etc.). So we exploit the FNDDS foodcode categories and sub-categories to classify each FAH item into one of the 29 production/manufacturing industries. A full list of the FNDDS foodcode categories and sub-categories are listed in Appendix D. An example will help illustrate how these codes were used to map items into the 29 production/manufacturing industries in the BEA IO tables. A food with the 8-digit FNDDS foodcode 63430110 is described as a "Sorbet, fruit, citrus flavor" and is assigned to an industry in Table 1 based on the first three digits of the code. The first three digits, 634, classify the item as a "Mixture of fruits and non-fruit items" and this item is produced by the BEA IO industry called Frozen Food Manufacturing. In some cases we used the first two digits of the FNDDS foodcode (in this case 63 = "Other fruits") or the first digit of the code (in this case 6 = "Fruits") to assign the FAH item to its production industry. For some foods the first four digits of the FNDDS foodcode



provided even more specific information describing the item so it could be categorized into one of the industries in Table 1.

Some FAH items purchased by households were not identified with a FNDDS foodcode. Instead they were assigned a 4-digit Food Pattern Equivalents Ingredients (FPID) foodcode. Items identified with FPID foodcodes are single ingredient foods and are used to construct the foods identified with FNDDS foodcodes. A list of FPID categories are listed in Appendix E. The first digit of the FPID foodcode defines the major food group of the item and in the majority of cases this first digit was used to assign FAH items to the appropriate production industry. In other cases, FPID coded foods were reviewed and assigned manually to their appropriate production industry. For example, if the first digit of the FPID foodcode is 9 the food is in the FPID category called “Fruit and fruit juice”. However, fresh, frozen, and canned fruit as well as fruit juice are produced by different BEA IO industries. Fresh fruit is produced by the fruit and nut farming industry. Frozen fruit is produced by the Frozen Food Manufacturing industry. Fruit juice and canned fruits are produced by the Dried, Canned, and Pickled Foods Manufacturing industry. In cases where the processing of an item was important in terms of how it was mapped into a production industry manual coding based on the FPID foodcode was conducted. Table 5 shows how many FAH items were mapped to production industries according to the number of digits in the FNDDS foodcode or the FPID foodcode utilized.

**Table 5. Summary of foodcode digit type used to map FAH items to production industries.**

| Foodcode type used to assign to emissions category | FAH items assigned to emissions category |         |
|--|--|---------|
|  | n  | %       |
| All 8 digits of FNDDS foodcode                     | 11,818                                   | 7.84%   |
| First 4 digits of FNDDS foodcode                   | 8,464                                    | 5.61%   |
| First 3 digits of FNDDS foodcode                   | 93,966                                   | 62.32%  |
| First 2 digits of FNDDS foodcode                   | 15,466                                   | 10.26%  |
| FPID four digit code                               | 21,061                                   | 13.97%  |
| Total items assigned*                              | 150,775                                  | 100.00% |
| Total FAH items in FoodAPS database                | 155,958                                  | -       |

\*There are 155,958 FAH items in the FoodAPS database, and approximately 5,183 could not be assigned to production industries because of missing item information. 944 items were also removed from the analysis during data processing because information on cost or weight seemed spurious.

Some FAH items were acquired for free because someone other than a member of the household purchased the item for a household member, or the item was acquired at a food bank or pantry. Mapping of these items into an appropriate IO production industry relied on the methodology as described above. However, USDA ERS imputed a cost for these items and so calculation of GHG emissions utilized this imputed value. Some free items or items missing cost information that were not assigned imputed values were excluded from our analysis (n=4,628, or 6.28% of all FAH items reported in FoodAPS).

**FAFH items**

FAFH items are foods purchased in bakeries, cafes, buffets, full service and limited service restaurants, coffee shops, drinking places, truck stops, casinos, and schools. 147,623 FAFH items were purchased by FoodAPS households were assigned to production industries in two ways depending on how many ingredients the item contained. First, single ingredient foods (i.e. milk,

coffee, apple, bottled water, etc.) were mapped into one of the 29 production industries in Table 1 based on the first four-digits of each item's What We Eat in America (WWEIA) foodcodes, also designed by USDA ARS. The WWEIA foodcodes group FNDDS foods into broader categories. For example, milk is the broader WWEIA food group and all types of milk (i.e. skim, whole, etc.) would be grouped into this category. The first two digits of the WWEIA foodcode classifies the food into a broad category and all four digits of the code classifies the food into a more specific category. We used the WWEIA foodcodes to categorize FAFH items instead of the FNDDS or FPID foodcodes because we assumed all FAFH items to be in the same processed form at the point of consumer purchase. 4,032 FAFH items (2.73% percent of total FAFH items) were assigned a production industry as single ingredient items using the WWEIA foodcodes.

However, not all FAFH items purchased by FoodAPS households were single ingredient items. Many FAFH items (n=40,997, 27.8% of all FAFH items) were mixed dishes such as burritos, pizzas, and hamburgers. For these items we used a different process for assigning items to production industries that required that we decompose each item into its single ingredient components. Then we mapped components to the appropriate production industry and GHG emissions were calculated for each component using the method outlined in Section 2.2.

The food components of these multi-ingredient mixed dishes are defined by the Food Pattern Equivalents Database (FPED). FPED food components are based on the food groups in the Dietary Guidelines for Americans (DGA). The FPED food components include: meat (beef, pork, lamb, veal, other, and including organ and cured types), poultry (including organ and cured), seafood, eggs, soy products, nuts and seeds, legumes, dark green vegetables, red and

orange vegetables, tomato products, starchy vegetables, white potatoes, other vegetables, fruits, juices, whole grains, refined grains, oils, solid fats, added sugars, and alcoholic drinks. We match each of these FPED components to an appropriate production industry. Table 5 shows how FPED components were matched to BEA IO production industries.

In some cases FPED components represented foods produced by multiple BEA IO industries. For example, the FPED component solid fats includes oils, margarine, shortening, and butter. These different types of solid fats are produced by different BEA IO industries and as such we could not use the FPED components to assign the item components to a production industry. Instead, we use the Food Intakes Converted to Retail Commodities (FICRCD) database to map FAFH mixed dish solid fat components to the appropriate production industries. FICRCD database provides information on the type and quantity of food commodities contained in each FNDDS item. Unlike FPED categories FICRCD categories distinguish between solid fats. Table 6 also summarizes how FICRCD, FPED, and BEA IO industries are matched for the solid fats FPED component.

**Table 6. FPED or FICRCD components to BEA IO production/manufacturing crosswalk**

| <b>FPED or FICRCD component</b> | <b>Production/manufacturing industry</b>                         |
|---------------------------------|--|
| <b>Protein foods</b>            |  |
| Meat (beef, pork, lamb, veal)   | Beef, pork, and other red meat                                   |
| Poultry                         | Poultry  |
| Seafood                         | Seafood products   |
| Eggs                            | Egg products   |
| Soy products                    | Soybean products   |
| Nuts and seeds                  | Fruits and tree nuts   |
| <b>Vegetables</b>               |  |
| Legumes                         | Canned, dried, and pickled foods                                 |
| Dark green vegetables           | Vegetables and melons  |
| Red and orange vegetables       | Vegetables and melons  |
| Tomato products                 | Canned, dried, and pickled foods                                 |
| Starchy vegetables              | Vegetables and melons  |
| Potatoes                        | Vegetables and melons  |
| Other vegetables                | Vegetables and melons  |
| <b>Fruits</b>                   |  |
| Citrus fruits                   | Fruits and tree nuts   |
| Juices                          | Canned, dried, and pickled foods                                 |
| Other fruits                    | Fruits and tree nuts   |
| <b>Grains</b>                   |  |
| Whole grains                    | Bread and bakery products <b>OR</b>                              |
| Refined grains                  | Cookies, crackers, pastas tortillas <b>OR</b><br>Flours and rice |
| <b>Oils</b>                     |  |
|                                 | Fats and Oils  |
| <b>Dairy</b>                    |  |
| Milk                            | Milk and butter  |
| Cheese                          | Cheese   |
| Yogurt                          | Milk and butter  |
| <b>Added sugars</b>             |  |
|                                 | Sugar and confectionary products                                 |
| <b>Solid fats</b>               |  |
| Butter*                         | Milk and butter  |
| Shortening*                     | Fats and Oils  |
| Margarine*                      | Fats and Oils  |
| Other solid fats*               | Milk and butter <b>OR</b> Fats and Oils                          |

Once FPED or FICRCD components were assigned to the appropriate BEA IO production industry we then calculated the ratio of the FPED or FICRCD component servings (in cups) to the total FPED or FICRCD component servings (in cups) in each FAFH mixed dish item. This ratio was then multiplied by the total cost (in dollars) of the FAFH mixed dish item to get the

proportion of the item's cost to be assigned to each production industry. Equation 5 summarizes this computation:

$$\text{Fraction } CE_i \text{ assigned to production industry } (FC_i) = \frac{\text{FPED OR FICRCD component (cups)}_i}{\sum_{n=1}^N \text{FPED OR FICRCD component (cups)}_i} \times CE_i \quad (5)$$

where  $CE_i$  is the consumer expenditure on item  $i$ . The term “FPED or FICRCD components (cups) <sub>$i$</sub> ” in the numerator on the right hand side of equation 5 represents the servings of each FPED or FICRCD component contained in item  $i$ . The denominator represents the total number of servings of FPED and FICRCD components contained in item  $i$ . To calculate the total number of cups of FPED and FICRCD components we had to first convert all FPED or FICRCD servings to cup equivalents because in some cases the FPED or FICRCD components are calculated in ounces, teaspoons, or grams. We used conversion factors available in the USDA FPED Methodology and Users Guide for 2011-2012 (available online at: <http://www.ars.usda.gov/>) and the USDA Food and Nutrition Service School Food Buying Guide (available online at: <http://www.fns.usda.gov/>) to convert all FPED and FICRCD components to cups.

A simplified example helps to illustrate how this process of decomposing each FAFH mixed dish into FPED or FICRCD components was conducted. A pizza, for example, might contain 0.75 cups of grains, 1.25 cups of cheese, 0.30 cups of red or orange vegetables (i.e. tomato sauce), 0.05 cups of oil, and 0.5 cups of meat. These FPED and FICRCD components are added together to obtain the total number of FPED or FICRCD components in the item. In this case there are 2.85 cups of FPED OR FICRCD components in the pizza. We then divide the number of cups of each FPED or FICRCD component in the food by the total to get each FPED or FICRCD component fraction ( $FC_i$ ). These fractions are then multiplied by the cost of the item ( $CE_i$ ) to get

the fraction of the item’s value that is then multiplied by the respective production industry EIF for each FPED or FICRCD component to obtain the GHG emissions for each component.

Equation 6 below shows how the calculation of GHG emissions was conducted for these FAFH mixed dish items:

$$\mathbf{GHGE}_i \text{ at producer/manufacturing level} = \sum_{m=1}^n \mathbf{CE}_i \times \mathbf{FC}_m \times \mathbf{EIF}_j \quad (6)$$

where the GHG emissions of item  $i$  is the sum-product of each  $m$  FPED or FICRCD fraction (FC) multiplied by the cost of item  $i$  and the respective FPED or FICRCD component’s  $j$  BEA IO production industry EIF. We then add the GHG emissions from post-production/manufacturing activities to the emissions calculated in equation 4 using the same process as outlined in Section 2.3.

It should be noted that we make the assumption that the value of each FPED or FICRCD component is the same in each item and so each item’s cost is a linear combination of the FPED or FICRCD components of which it is composed. This assumption introduces some uncertainty in our analysis and we will note this in our discussion section.

**Imputing cost and assigning emissions for FAFH items purchased in schools and restaurant combination meals**

FAFH items purchased in schools (n=28,289, or 19.16% of all FAFH items) by children between the ages of 11 and 17 were assigned to production industries in the same way as other single ingredient and mixed dish items as listed in the preceding sections. However, in some cases school items were free or cost information was not reported in FoodAPS. Additionally, FAFH items were in some instances reported as bundles or combos (i.e. fast food value meal with a

hamburger, French fries, and soft drink) and contained only one price for the entire bundle. FoodAPS households reported purchasing 19,606 bundled/combo meals (12.73% of total FAFH items purchased). These items were mapped to production industries like other FAFH items either as single ingredient or multi-ingredient items as outlined in Section 2.2. However, we imputed the cost of items in combination meals using the restaurant or school, FoodAPS survey primary sampling unit (PSU), and FNDDS foodcode specific average a la carte cost for the items (excluding tax and tip). Households reported the restaurant from which they purchased FAFH items, the majority of which were purchased from the top 60 fast food and casual dining restaurants in the U.S. according to the *Quick Service Restaurant* magazine ranking of fast food restaurants and in *Restaurants and Institutions* (2009). Items were also purchased at schools or at “generic” restaurants which are restaurants not included in this top 60 list. For these items we used the generic restaurant or school, PSU, and FNDDS foodcode specific average a la carte item price to impute item cost. In total approximately 45% of the FAFH items required cost imputation.

### **Calculating total weekly GHG emissions by household per SAE**

Total GHG emissions for each household per week are calculated by summing the GHG emissions for both FAH and FAFH items purchased by each  $k$  household. We account for differences in calorie requirements across FoodAPS households in our calculation of GHG emissions per household. The number of Standard Adult Equivalent (SAE) in each FoodAPS household is calculated using the USDA Center for Nutrition Policy and Promotion (CNPP) estimate of calorie requirements per day by age and gender groups for all household members, including children, men, women, and women who are pregnant or breastfeeding. (Center for Nutrition Policy and Promotion 2010). For calculating SAEs per household we assume all



FoodAPS household members are sedentary and calorie needs per household member are estimated accordingly. Estimating GHG emissions per SAE is more appropriate than GHG emissions per household member as household members have different nutrient and energy requirements. Calculating GHG emissions in this way is an innovation because previous studies of dietary GHG emissions did not have detailed data on household composition.

We calculate the means and linearized standard errors adjusting for complex survey design and report our results across the entire FoodAPS sample or by the four income group strata defined in Section 2.1. We also calculate GHG emissions per household per SAE per week across different household types. The next section contains descriptive and preliminary results only from our analysis thus far and these results will be updated in future versions of the manuscript.

### **3. RESULTS**

#### ***3.1 Average total GHG emissions per household and per SAE per week***

We find that the average total GHG emissions per household per week is 58.70 kg CO<sub>2</sub>e (95% Confidence Interval (95% CI) = 55.10, 62.29; n=4,723) and 29.52 kg CO<sub>2</sub>e per SAE per week (95% CI = 27.82, 31.23, n=4,723). This is equivalent to traveling 139 miles and 70 miles, respectively in the average U.S. passenger vehicle (US EPA 2016). The average GHG emissions from FAH purchases per household per SAE per week is 13.65 kg CO<sub>2</sub>e (95% CI = 12.85, 14.46 kg CO<sub>2</sub>e, n=4,723) and 15.86 kg CO<sub>2</sub>e per household per SAE per week (95% CI = 14.61, 17.12 kg CO<sub>2</sub>e, n=4,723) for FAFH purchases.

We compare our results to previously published estimates of the carbon footprint of U.S. household diets and food expenditures (Table 7). In order to compare our estimates to these previous studies we divide the average total GHG emissions per day per household by the within sample average household size which is equal to 2.45. As the data presented in Table 7 show our estimate of GHG emissions per capita per day is relatively lower than previous estimates. In particular, our estimate is roughly half that found in the two other studies using EIO-LCA to estimate GHG emissions of U.S. household food expenditures (Jones and Kammen, 2011 and Weber and Matthews, 2008). We will explain why our estimate is lower than these other studies in our discussion section.

**Table 7. Comparison of our GHG emissions estimate of FoodAPS expenditures to previously published estimates of GHG emissions of U.S. diets or food expenditures. Table is in order of year of publication.**

| Year of publication | Study                         | kg CO <sub>2</sub> e day <sup>-1</sup> capita <sup>-1</sup> | Method used to calculate GHG emissions |
|---------------------|-------------------------------|---|--|
| 2016                | Present study                 | 4.2   | EIO-LCA                                |
| 2014                | Heller and Keoleian           | 3.6   | PLCA compilation                       |
| 2011                | Jones and Kammen              | 6.4   | EIO-LCA                                |
| 2009                | Bon Appetit* †                | 7.6   | PLCA compilation                       |
| 2009                | Conservation International* † | 7.7   | PLCA complication/EIO-LCA              |
| 2009                | The Nature Conservancy* †     | 10.2  | Other method                           |
| 2008                | Weber and Matthews            | 8.6   | EIO-LCA                                |
| 2009                | Carbonify.com* †              | 4.1   | Other method                           |
| 2009                | EPA, agriculture only*        | 4.3   | Other method                           |

\*Taken from Kim and Neff (2009) and details of methods used by these studies/organizations to calculate GHG emissions can be found in that publication.  
† Not peer reviewed.

Next we show the source of GHG emissions for food expenditures by production stage in the food supply chain (i.e. production, wholesale, transportation (air, water freight, truck, and rail), retailing, and restaurant activity) for each of the 29 production/manufacturing industries. Figure

2 shows average total household GHG emissions per week from purchases of foods from each of the 29 production/manufacturing industries for both FAH and FAFH items purchased by FoodAPS households. Black error bars show one standard error of mean estimates for each production/manufacturing industry. Standard errors are calculated as the sum of the standard errors of the average total GHG emissions for each supply chain stage of each production/manufacturing industry.

### ***3.2 Source of GHG emissions by production/manufacturing industries and supply chain stage***

We find the average total household GHG emissions (in kg CO<sub>2</sub>e) per week for FAH items purchased from the beef, pork, lamb, and other red meat production/manufacturing industry ( $5.29 \pm$  one standard error (SE) =  $0.16$  kg CO<sub>2</sub>e household<sup>-1</sup> week<sup>-1</sup>) are the highest of any production/manufacturing industry followed closely by wine ( $4.58 \pm$  SE =  $0.56$  kg CO<sub>2</sub>e household<sup>-1</sup> week<sup>-1</sup>), poultry ( $4.30 \pm$  SE =  $0.16$  kg CO<sub>2</sub>e household<sup>-1</sup> week<sup>-1</sup>), beer ( $4.08 \pm$  SE =  $0.27$  kg CO<sub>2</sub>e household<sup>-1</sup> week<sup>-1</sup>), and frozen foods ( $3.67 \pm$  SE =  $0.16$  kg CO<sub>2</sub>e household<sup>-1</sup> week<sup>-1</sup>). Average total GHG emissions are lowest for breakfast cereals, seasonings and dressings, sugar and confectionary products, and eggs.

Overall the largest share of average total GHG emissions across all production/manufacturing industries occurs at the production or manufacturing stage (the blue part of the bar graph) for FAH items. The retail stage of the supply chain accounts for the second largest share of average total GHG emissions.

**Figure 2. Average total household GHG emissions (kg CO<sub>2</sub>e) per week for FAH purchases for each of the 29 food production/manufacturing industries, decomposed by supply chain stage (n=4,354). Black bars indicate one standard error of the estimated mean.**

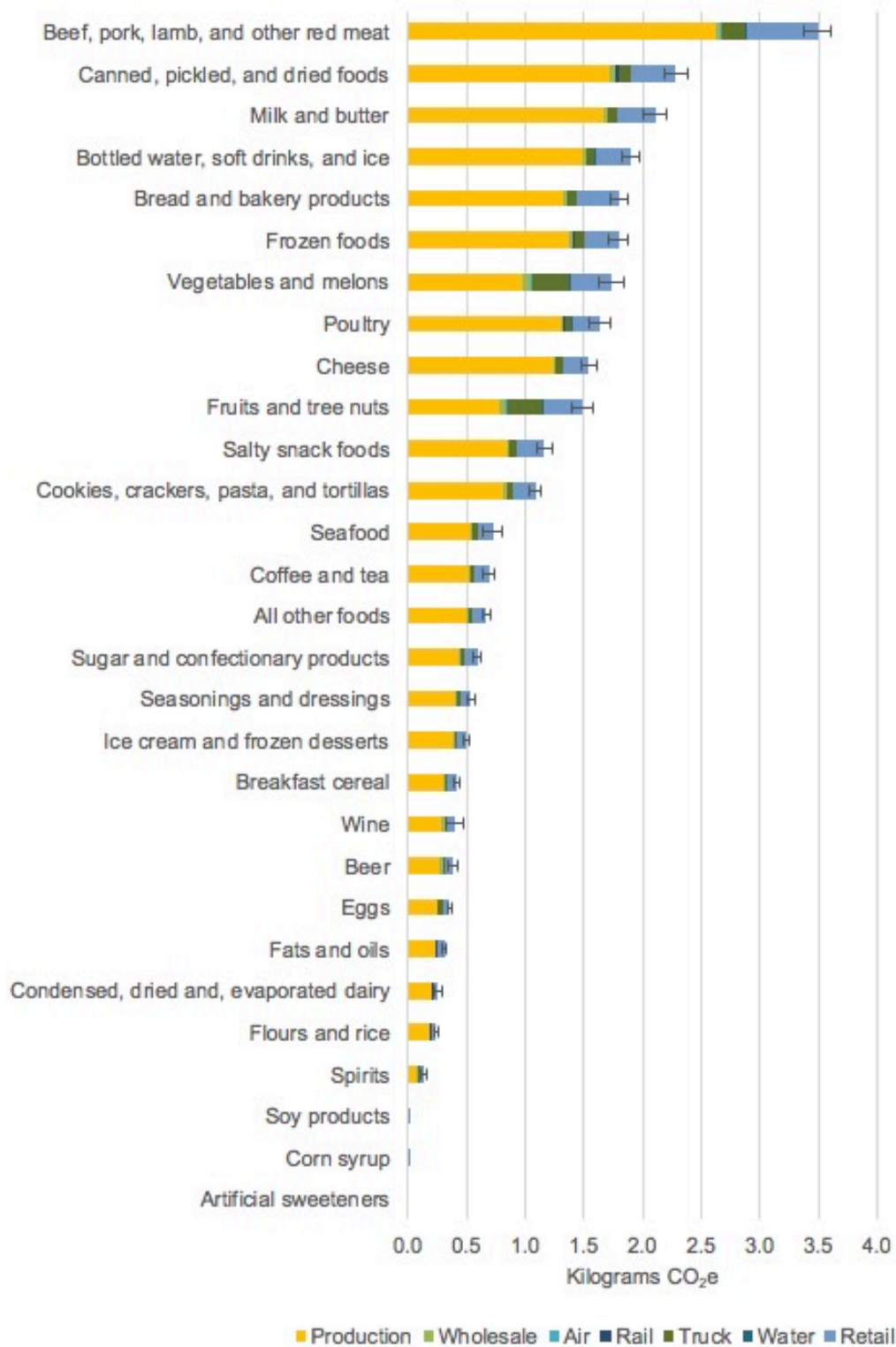
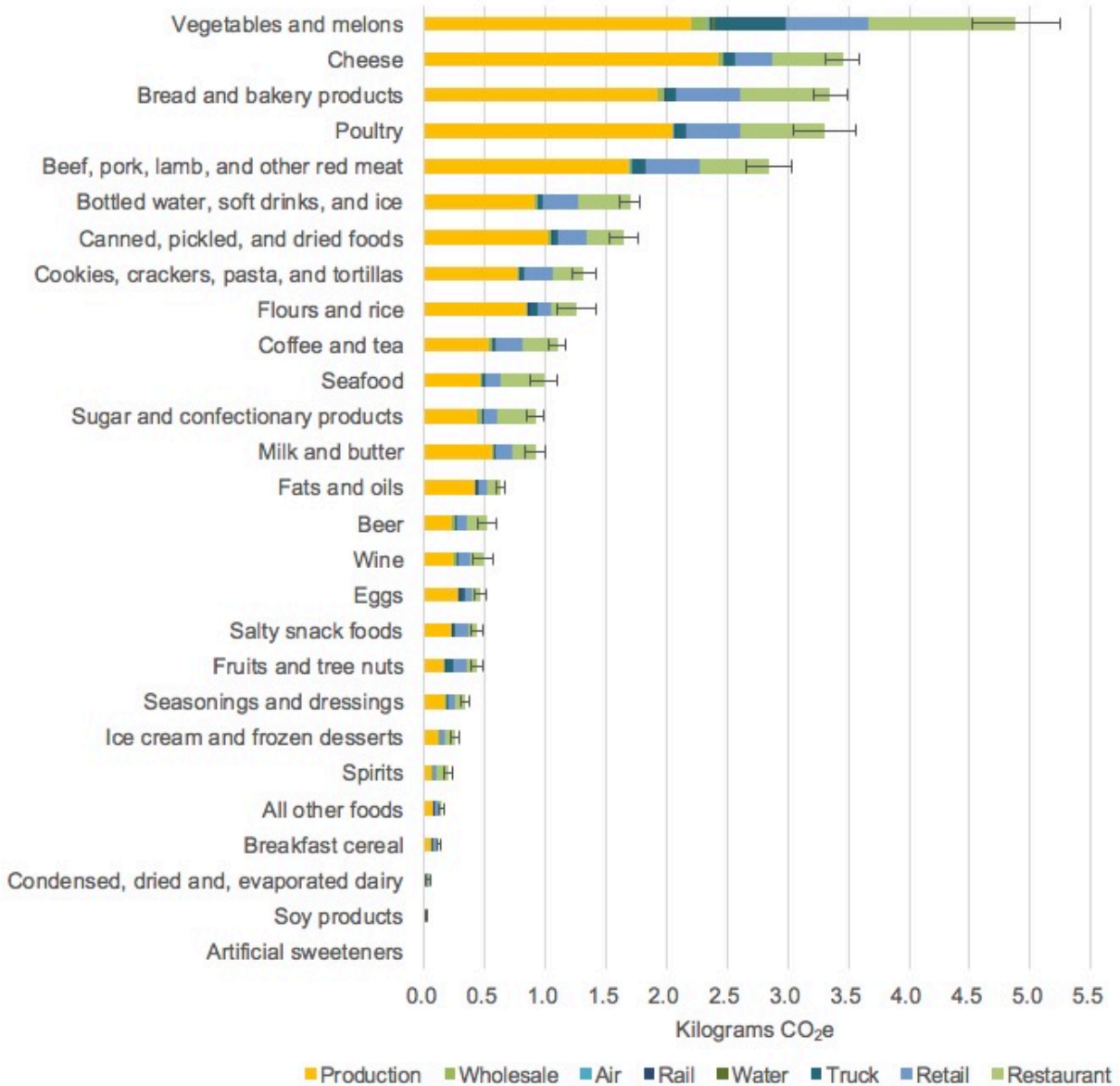


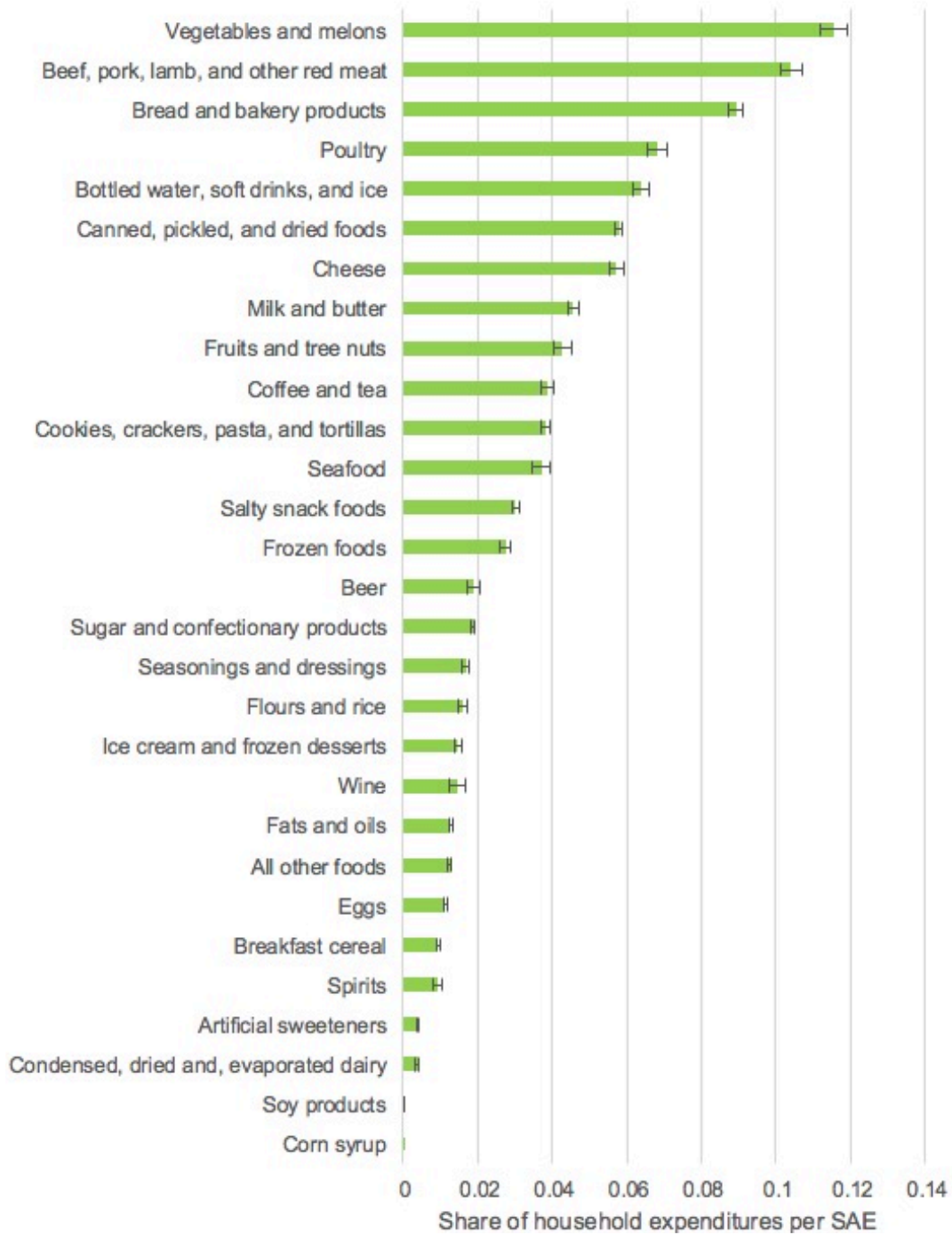
Figure 3 shows average total household GHG emissions (in kg CO<sub>2</sub>e) per week for FAFH items for each of the production/manufacturing industries for all supply chain stages, including the restaurant industry. The black error bars in Figure 3 represent one standard error of the estimated mean for each of the 29 production/manufacturing industries. We find that average total GHG emissions per household per week are highest for vegetables and melons (mean =  $4.30 \pm 1$  SE =  $0.37$  kg CO<sub>2</sub>e household<sup>-1</sup> week<sup>-1</sup>), cheese (mean =  $3.36 \pm 1$  SE =  $0.14$  kg CO<sub>2</sub>e household<sup>-1</sup> week<sup>-1</sup>), bread and bakery products (mean =  $3.26 \pm 1$  SE =  $0.14$  kg CO<sub>2</sub>e household<sup>-1</sup> week<sup>-1</sup>), poultry (mean =  $3.22 \pm 1$  SE =  $0.26$  kg CO<sub>2</sub>e household<sup>-1</sup> week<sup>-1</sup>), and beef, pork, lamb and other red meat (mean =  $2.73 \pm 1$  SE =  $0.19$  kg CO<sub>2</sub>e household<sup>-1</sup> week<sup>-1</sup>). Average total GHG emissions per household per week are lowest for artificial sweeteners, soy products, and condensed, dried, and evaporated dairy. The restaurant and production and manufacturing stages of the supply chain account for the largest share of GHG emissions for the majority of the 29 food production/manufacturing industries.

**Figure 3. Average total household GHG emissions (kg CO<sub>2</sub>e) for FAFH items for each of the 29 food production/manufacturing industry, decomposed by supply chain stage (n=4,200). Black bars indicate one standard error of the estimated mean.**



Figures 5 and 6 show the average share of household food expenditures and GHG emissions per SAE per week in for each of the food production/manufacturing industries. The largest share of both expenditures and GHG emissions result from expenditures on: vegetables and melons; beef, pork, lamb, and other red meat; cheese, bread and bakery products, and poultry products.

**Figure 5. Average household share of food expenditures by production/manufacturing industry (n=4,723).**



**Figure 6. Average household share of GHG emissions by production/manufacturing industry (n=4,723).**

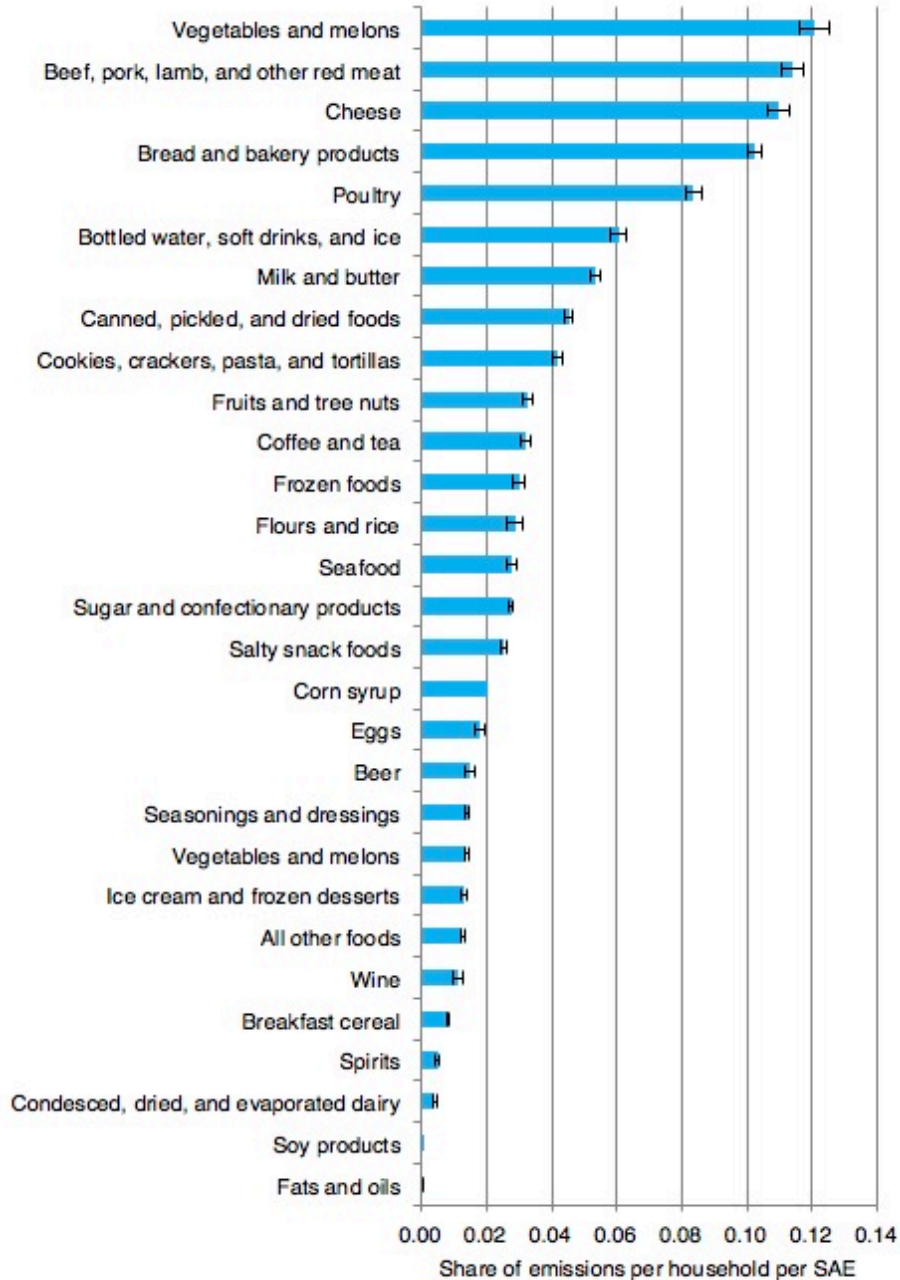


Table 8 below shows average total GHG emissions per household per SAE per week for the four FoodAPS income group strata. Households on SNAP or with incomes  $\leq 185\%$  FPT have



significantly lower emissions per SAE per week compared to both households that do not participate in SNAP and those with incomes >185% FPT.

**Table 8. Average total GHG emissions (in kg CO<sub>2</sub>e) per household per SAE per week by FoodAPS income groups**

| FoodAPS income group | kg CO <sub>2</sub> e SAE <sup>-1</sup> | Standard error (SE) | CI Lower bound | CI Upper bound | n     |
|----------------------|--|---------------------|----------------|----------------|-------|
| SNAP                 | 21.52                                  | 0.83                | 19.85          | 23.18          | 1,581 |
| NS <100% FPT         | 23.03                                  | 2.18                | 18.66          | 27.40          | 434   |
| NS 100-185% FPT      | 21.87                                  | 0.84                | 20.19          | 23.55          | 878   |
| NS >185% FPT         | 30.60                                  | 1.00                | 28.60          | 32.59          | 1933  |

As table 9 shows the increased emissions for higher income households can be explained by increased spending on food. Households with incomes greater than 185% FPT spend roughly \$25-\$30 dollars more per SAE per week than lower income households in the sample.

**Table 9. Average total expenditures (in dollars) per household per SAE per week by FoodAPS income groups**

| FoodAPS income group | Mean Expenditure SAE <sup>-1</sup> | Standard error (SE) | CI lower bound | CI upper bound | n     |
|----------------------|------------------------------------|---------------------|----------------|----------------|-------|
| SNAP                 | 62.25                              | 2.49                | 57.26          | 67.25          | 1,581 |
| NS <100% FPT         | 68.48                              | 6.16                | 56.14          | 80.82          | 434   |
| NS 100-185% FPT      | 65.81                              | 2.48                | 60.83          | 70.78          | 878   |
| NS >185% FPT         | 96.23                              | 3.30                | 89.62          | 102.85         | 1,933 |

We also find a positive association between average total GHG emissions per household per SAE per week and the highest level of education achieved by any household member. This positive association is likely mediated by income as educational attainment and income are highly correlated. We will more formally explore this relationship in a later version of this manuscript.

**Table 10. Average total GHG emissions per household per SAE per week by highest level of education achieved by any household member.**

| Education category       | kg CO <sub>2</sub> e<br>SAE <sup>-1</sup> | Standard<br>error (SE) | CI lower<br>bound | CI upper<br>bound | n     |
|--------------------------|---|------------------------|-------------------|-------------------|-------|
| <12 years of school      | 20.10                                     | 0.90                   | 21.90             | 18.31             | 801   |
| High school graduate     | 25.30                                     | 0.85                   | 27.01             | 23.60             | 1,351 |
| Some college             | 28.08                                     | 0.97                   | 30.04             | 26.13             | 1,554 |
| Bachelor's degree        | 36.26                                     | 2.37                   | 41.00             | 31.51             | 691   |
| Masters degree or higher | 39.25                                     | 1.98                   | 43.21             | 35.29             | 326   |

### ***3.2 Variation in GHG emissions across different dietary patterns***

We now present how changes in household food expenditures and dietary patterns can result in lower GHG emissions and potentially lower food costs. First, we identify common dietary patterns according to the food expenditures that FoodAPS households make in the 29 production/manufacturing industries. These dietary patterns include: (1) unrestricted or omnivorous diet, (2) diets excluding red meat, (3) lacto-ovo vegetarian diet, (4) pescatarian diets (lacto-ovo vegetarian diet with seafood consumption), (5) vegan diet, (6) diets excluding cheese, (7) diets excluding bottled water and soft drinks, (8) and diets excluding chicken. We find significant shares of households in the FoodAPS sample that follow these patterns, at least according to their self-reported expenditures and the number of households reporting these patterns are listed in the last row of Table 11. We calculate average total GHG emissions per household per SAE per week for households whose spending corresponds to these diet types. Table 11 shows the results of this analysis and we find significant GHG emissions reductions when households reduce the food spending on animal products and bottled water and soft drinks. Table 12 then shows how household food spending varies according to these types of diets.

**Table 11. Average total GHG emissions (in kg CO<sub>2</sub>e) per household per SAE per week for five seven dietary patterns observed in the FoodAPS sample.**

| Diet type                        | kg co <sub>2</sub> e per household per SAE per week | Standard error (SE) | CI lower bound | CI upper bound | n     |
|----------------------------------|---|---------------------|----------------|----------------|-------|
| Average sample omnivorous diet   | 29.52   | 0.85                | 27.82          | 31.23          | 4,826 |
| No red meat                      | 15.74   | 1.28                | 13.18          | 18.30          | 512   |
| Lacto-ovo vegetarian             | 10.31   | 1.43                | 7.44           | 13.18          | 284   |
| Pescatarian                      | 11.27   | 1.35                | 8.57           | 13.97          | 332   |
| Vegan                            | 7.13  | 1.49                | 4.15           | 10.10          | 224   |
| No cheese                        | 16.03   | 0.89                | 14.25          | 17.82          | 775   |
| No bottled water and soft drinks | 24.30   | 1.39                | 21.50          | 27.09          | 887   |
| No chicken                       | 20.00   | 0.99                | 18.00          | 21.99          | 1106  |

**Table 12. Average total food expenditures per household per SAE per week for seven dietary patterns observed in the FoodAPS sample.**

| Diet type                        | expenditures (\$) per household per SAE per week | Standard error (SE) | CI lower bound | CI upper bound | n     |
|----------------------------------|--|---------------------|----------------|----------------|-------|
| Average sample omnivorous diet   | 29.52  | 0.85                | 27.82          | 31.23          | 4,826 |
| No red meat                      | 15.74  | 1.28                | 13.18          | 18.30          | 512   |
| Lacto-ovo vegetarian             | 10.31  | 1.43                | 7.44           | 13.18          | 284   |
| Pescatarian                      | 11.27  | 1.35                | 8.57           | 13.97          | 332   |
| Vegan                            | 7.13   | 1.49                | 4.15           | 10.10          | 224   |
| No cheese                        | 16.03  | 0.89                | 14.25          | 17.82          | 775   |
| No bottled water and soft drinks | 24.30  | 1.39                | 21.50          | 27.09          | 887   |
| No chicken                       | 20.00  | 0.99                | 18.00          | 21.99          | 1106  |

#### 4. DISCUSSION

Overall we find that GHG emissions of U.S. household food expenditures per capita are lower than previous estimates. Our estimate of 4.2 kg CO<sub>2</sub>e per capita per day is similar to more recent estimates of U.S. household per capita GHG emissions (i.e. Heller and Keoleian, 2014), but much lower than previous estimates using EIO-LCA methods. There are several reasons that could explain the difference in emission estimates, including: underreporting of food expenditures in the FoodAPS survey, specific accounting of food consumption by children in

schools which is lower cost than food purchased in retail outlets, increases in resource use efficiency in the food production/manufacturing industries in the U.S. economy which results in fewer GHG emissions, and/or changes in food demand by U.S. consumers. Differences in the methodology and survey data used used to calculate GHG emissions using EIO-LCA could also explain the difference in per capita emissions estimates.

Regardless of these discrepancies we have identified in more detail the sources of GHG emissions in the food system. We show that the majority of GHG emissions caused by U.S. household food consumption originate in sectors that produce animal products such as beef, pork, lamb, and other red meat, poultry, and cheese. We also find significant emissions result from the consumption of vegetables and melons, bread and bakery products, and bottled water and soft drinks. In particular, the consumption of bottled water and soft drinks accounts for a relatively large share of GHG emissions of household food consumption and to date no study has show this to be the case. Thus, future strategies to curb household GHG emissions from food consumption may need to make recommendations about the consumption of beverages such as bottled water and soft drinks. Reducing consumption of soft drinks in particular may also lead to improved health outcomes since these items have been indicted as a leading culprit in the obesity epidemic.

We also show that GHG emissions increase quite dramatically for higher income households, but remain fairly constant for lower income households. We also found that households with higher educational attainment have higher GHG emissions from food expenditures. This relationship is likely mediated by income and further testing and regression analysis will be used to determine if that is the case.

Finally, we show how household GHG emissions from food vary according to different dietary patterns. We find that household GHG emissions are significantly lower for households who do not purchase animal products and bottled water and soft drinks. This finding confirms what previous literature has suggested, which is that animal products, especially beef and other red meats contribute significantly to food system GHG emissions.

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## 7. APPENDICES

### Appendix A. Definitions of each production/manufacturing industry

| Production/manufacturing industry | Items produced by the production/manufacturing industry  |
|-----------------------------------|--|
| Vegetables and melons             | Acorn squash, artichoke, asparagus, bean (except dry), beet (except sugar), broccoli, Brussel sprout, butternut squash, cabbage, cantaloupe, carrot, casaba melon, cassava, cauliflower, celery, Chinese pea, chive, collard, cowpea (except dry), crenshaw melon, cucumber, dill, eggplant, endive, English escarole, garlic, gingerroot, green bean, green cowpea, green lima bean, green pea, honeydew, kale, leek, lettuce, melon, muskmelon, okra, onion, parsley, parsnip, pea (except dry), pepper, pumpkin, radish, rhubarb, romaine, rutabaga, shallot, snap bean, snow pea, spaghetti, spinach, squash, string bean, sweet corn, sweet pepper, taro, tomato, watermelon, zucchini, excludes greenhouse products, includes vegetables and melons grown for seeds and seedlings/plants; potato; sweet potato; yam; Mushrooms, alfalfa sprout, bean sprout, eggplant, cucumber, endive, English pea, escarole, fruit, garlic, gingerroot, ginseng, herb, hydroponic crop farming, melon, rhubarb, spice, tomato, truffles, vegetables |
| Fruits and tree nuts              | Almonds, brazil nut, cashew, filbert, hazelnut, macadamia, pecan, pistachio, tree nut, walnut, grapefruit, lemon, lime, mandarin orange, tangelo, tangerine, apple, grape, raisin, strawberry, blackberry, boysenberry, cranberry, currant, dewberry, gooseberry, huckleberry, loganberry, raspberry, youngberry, apricot, avocado, banana, cactus, cherry, coconut, coffee, date, fig, guavas, kiwi fruit, mango, nectarine, non-citrus fruit, olive, papaya, passion fruit, peach, pear, persimmon, pineapple, plantain, plum, pomegranate, prickly pear, prune, quince.   |
| Eggs                              | Eggs   |

|                  |  |
|------------------|--|
| Flours and rice  | Barley flour; prepared batters made in flour mills; blended flour made in flour mills; brewers/distillers flakes and grits from corn; buckwheat flour; bulgur flour; cereal grain flour; cereal grain germ; corn flour; corn meal made in flour mills, doughs prepared in flour mills; durum flour; farina except breakfast food made in flour mills; flour mixes; blended prepared or self-rising flours (except rice); fruit flour, graham flour; grits and flakes; hominy grits (except breakfast food); corn meal; flour mixes (biscuit, cake, doughnut, pancake); oat flour; potato flour; prepared flour mixes made in flour mills; rye flour; semolina flour; sorghum flour; vegetable flour; vegetable flour/meal/powders; wheat bran; wheat flour; wheat germ; rice flour; rice milling; rice mixes (uncooked and packaged with other ingredients) made in rice mills; various malts. |
| Corn syrup       | Corn starch, corn oil, margarine, tapioca, corn syrup (of the edible products in this category)  |
| Fats and oils    | Canola, coconut oil, corn, cottonseed, hydrogenating purchased oil, linseed oil, margarine-butter blend, margarines, olive oil, palm-kernel oil, peanut oil, rapeseed (canola), safflower oil, shortening, soybean cooking oil, table oil, tree nut oils, vegetable oil (of the edible products in this category)  |
| Soybean products | Soybean oil and other soybean products   |
| Breakfast cereal | Breakfast cereal, corn breakfast foods, farina, flour mills for breakfast cereal, grain mills for breakfast cereal, granola cereal (except bars and clusters), hominy grits for breakfast cereal, dry infant cereal, instant hot cereal, mix grain breakfast, oatmeal, oats, rolled oats, rice breakfast cereal, wheat breakfast cereal  |



|  |   |
|--|---|
| <p>Sugar and confectionery product manufacturing</p> | <p>Baking chocolate; candy stores, chocolate, candy made on premises not for immediate consumption; chocolate (coating, instant, liquor, syrups); chocolate coating and syrups; chocolate covered candy bars; chocolate covered granola bars; cocoa powdered drink; powdered cocoa; cocoa powdered mixes; cocoa drink powdered mixes; fudge; chocolate granola bars and clusters; chocolate liquor; chocolate covered nuts; syrup; Baking chocolate made from cacao beans; candy bars including chocolate covered made from cacao beans; chocolate candy made from cacao beans; chocolate (coatings, instant, liquor, syrups) made from cacao beans; chocolate bars made from cacao beans; chocolate confectionary made from cacao beans; chocolate coatings made from cacao beans; cocoa (instant, mix, mixed with other ingredients, powder drink, powdered) made from cacao beans; cocoa butter made from cocoa beans; confectionery chocolate made from cacao beans; cooking chocolate made from cacao beans; cocoa powdered drink mixes made from cacao; fudge made from cacao beans; chocolate granola bars and clusters made from cacao beans; chocolate liquor made from cacao beans; chocolate covered nuts from cacao beans; chocolate syrup made from cacao beans; sugar processing and turning raw cane sugar into cane sugar; Breakfast bars (non-chocolate covered); confectionary cake ornaments; candied fruits and fruit peels; nonchocolate candy bars; nonchocolate candy stores not for immediate consumption; chewing gum base and chewing gum manufacturing; nonchocolate confectionary; corn confections; cough drop (except medicated) manufacturing; crystallized fruits and fruit peel; sugared and stuffed dates; fruit peel products (candied, crystallized, glazed); fruits (candied, crystalized, glazed), non chocolate fudge; granola bars and clusters non chocolate; halvah; hard candies, jelly candies; licorice candy; lozenges non-medicated; marshmallows and marshemellow cream; marzipan; covered nuts; popcorn balls; candy covered popcorn; synthetic chocolate; toffee.</p> |
| <p>Frozen foods</p>                                  | <p>This industry comprises establishments primarily engaged in manufacturing frozen fruit, frozen juices, frozen vegetables, and frozen specialty foods (except seafood), such as frozen dinners, entrees, and side dishes; frozen pizza; frozen whipped toppings; and frozen waffles, pancakes, and french toast. EXCLUDES: ice cream and frozen desserts; frozen bread and bakery; animal slaughtering and processing (i.e. frozen meats).</p>  |

|   |   |
|---|---|
| Canned, pickled, and dried foods              | Canned artichokes; barbeque sauce, canned berries, fruit and vegetable juices; brining of fruits and vegetables, canning fruits and vegetables, canning jams and jellies, catsup, chili sauce, fruit brining, fruit butters, fruit juice canning, fresh fruit juice, fruit pickling, canned fruit pie filling, fruit picklings, canned fruits, canned hominy, horseradish (except sauce); jellies and jams, canned vegetable and fruit juices; fresh vegetable and fruit juices; ketchup; marmalade; mushrooms; olives, onions, canned fruit and vegetable pastes; pickles, pickling fruits and vegetables; imitation preserves canning; relishes canning; salsa canning; salsa canning, tomato based sauces; sauerkraut; spaghetti sauce; vegetable brining; vegetable canning; vegetable juice canning; fresh vegetable juice; vegetable pickling; baby foods (including meats) canning; baked beans; bouillon canning; broth (except seafood) canning; canning soups (except seafood); chili con carne canning; chinese foods canning; dry beans canning; gravy canning; infant and junior food canning; italian foods canning; meat canning for baby food; mexican foods canning; nationality speciality foods canning; pasta based products canning; pasta based products canning; pork and beans canning; spaghetti canning; bouillon made in dehydration plant; dried dates; dehydrating fruits and vegetables; dehydrating potato products; freeze-dried food processing for fruits and vegetables; fruit and vegetables dehydrating; artificially dried grapes; noodle mixes made in dehydration plants; dried olives; potato products (flakes/granules); dried prunes; raisins made in dehydration plants; rice mixes (uncooked and packaged with other ingredients) made in dehydration plants; salad dressing mixes; dry sauce mixes; soup mixes; sulphered fruits and vegetables manufacturing; vegetables dehydrating |
| Cheese  | Cheese (except cottage); cheese analogs; imitation or substitute cheese products; cheese spreads; natural cheese; cheese curds made in a cheese plant; cheese based dips; processed cheese; cheese spreads; raw liquid whey. EXCLUDES: Cheese based salad dressings and cottage cheeses   |
| Dry, condensed, and evaporated dairy products | Baby formula (fresh, processed, and bottled); dairy and non dairy based dietary beverages; dry and wet casein; condensed milk; condensed, evaporated and powdered whey; dried and powdered cream; dairy food canning; dehydrated milk; dry milk, dry milk products and mixtures; canned eggnog; evaporated milk; feed grade dry milk products; ice cream mix; ice milk mix; lactose manufacturing; malted milk; dietary milk based drinks; concentrated, condensed, dried, evaporated and powdered milk; malted milk; powdered milk, ultra high temperature milk; milkshake mixes; ice cream mix; dry nondairy creamers; nonfat dry milk; powdered milk; condensed, dried, evaporated, powdered whey; dry mix whipped topping; yogurt mix.  |

|                                     |   |
|-------------------------------------|---|
| Milk and butter                     | Acidophilus milk; milk based beverages (except dietary); buttermilk; cottage cheese; chocolate drink (milk based); chocolate milk; cream; sour cream based dips; chocolate milk drink; fresh eggnog (except canned); flavored milk drink; fluid milk substitutes processing; homogenizing milk; milk based drinks (except dietary); milk pasteurizing; milk processing (bottling, homogenizing, pasteurizing, vitaminizing); milk substitutes; fluid milk (except canned); liquid nondairy creamers; sour cream; sour cream substitutes; whipped topping (except dry frozen mix); whipping cream; yogurt (except frozen).   |
| Ice cream and frozen desserts       | Frozen custard; frozen desserts (except bakery); frozen custard; frozen fruit pops; ice cream; ice cream specialties; ice milk; ice milk specialties; flavored sherbet ices; frozen juice pops; frozen pudding pops; sherbets; frozen tofu desserts; frozen yogurt.   |
| Poultry                             | Canning poultry (except baby and pet food); fresh, frozen, canned, cooked chicken processing; chicken slaughtering and dressing; dressing small game; fresh, frozen, canned, cooked duck processing; duck slaughtering and dressing; fresh, frozen, canned, cooked geese processing; geese slaughtering and dressing; poultry ham manufacturing; poultry hot dogs; poultry luncheon meats; poultry meat canning; meat products made from a combination of poultry and other meats; poultry slaughtering, dressing, packing; processed poultry manufacturing; rabbit processing; rabbit slaughtering and dressing; small game processing; small game slaughtering, dressing and packing; turkey processing (fresh, frozen, canned, cooked); turkey slaughtering and processing.  |
| Beef, pork, lamb and other red meat | Abattoirs; animal fats (except poultry and small game) produced in slaughtering plants; slab and sliced bacon produced in slaughtering plants; beef carcasses, half carcasses, primal and subprimal cuts produced in slaughtering plants; beef produced in slaughtering plants; boxed beef produced in slaughtering plants; boxed meats produced in slaughtering plants; canned meats (except poultry) produced in slaughtering plants; cured hides and skins produced in slaughtering plants; custom slaughtering; animal fats (except poultry and small game) produced in slaughtering plants; hams except poultry; hot dogs except poultry); horsemeat; lamb carcasses, lamb produced in slaughtering plants; luncheon meat except poultry; meat canning except poultry; meats fresh, chilled or frozen (except poultry and small game); cured and smoked meats; pork carcasses; sausage casings; tallow; variety meats and edible organs; veal carcasses. |
| Seafood                             | Canning fish, crustacea and molluscs; curing fish and seafood; drying fish and seafood; Fish curing, drying, pickling, salting and smoking; seafood and seafood products canning; seafood and seafood products curing; seaweed processing (e.g. dulse); shellfish and shellfish products canning; shellfish curing; frozen seafood dinners; fish freezing; picking crab meat; shucking and packing fresh shellfish.   |

|  |  |
|--|--|
| Bread and bakery products                          | Bakeries with baking from flour on the premises, retailing not for immediate consumption. Bagels made in commercial bakeries; fresh bakery products (bread, cakes, doughnuts, pastries); bread type biscuits; bread and bread-type rolls; baking cakes (except frozen); commercial bakeries; communion wafers; croissants made in commercial bakeries; croutons and bread crumbs; crullers; doughnuts; frozen bread and bread-type rolls; knishes (except frozen); matzo baking; pastries (danish, french) made in commercial bakeries; fresh pies made in commercial bakeries; soft pretzels; sweet yeast goods (except frozen); unleavened bread made in commercial bakeries; frozen baked goods; frozen cake; frozen crullers; frozen bakery desserts; frozen doughnuts; frozen cake; frozen knishes; frozen pastries; frozen pies; frozen sweet yeast goods. EXCLUDES: cookies and crackers; bakery products for immediate consumption; retailing bakery products not for immediate consumption made elsewhere; manufacturing pretzels (excluding soft). |
| Cookie, cracker, pasta, and tortilla manufacturing | Dry bakery products (biscuits, cookies, crackers); ice cream cones; cookies, filled cookies; crackers (soda, graham); graham wafers; saltines; soda crackers; prepared batters from purchased flour; bread and bread-type roll mixes made from purchased flour; cake mixes made from purchased flour; cookie dough made from purchased flour; refrigerated or frozen doughs made from purchased flour; dry mixes made from purchased flour; blended or self-rising flour made from purchased flour; frozen doughs made from purchased flour; pancake mixes made from purchased flour; uncooked pastries; uncooked pie crust shells made from purchased flour; pizza doughs made from purchased flour; prepared flour mixes, refrigerated doughs; dry pasta manufacturing; dry pasta packaged with other ingredients made in pasta dry plants; dry egg noodles; dry macaroni; noodle mixes made in dry pasta plants; dry spaghetti; tortillas.  |
| Salty snack foods                                  | Canned nuts; Roasting/processing kernels, nuts, seeds; salted, roasted, cooked, canned nuts; peanut butter blended with jelly; peanut butter manufacturing; roasted nuts and seeds; canned, cooked, roasted, salted seeds; cheese curls and puffs; corn chips and related corn snacks; popped popcorn (except candy covered); pork rinds; potato chips; potato sticks; pretzels (Except soft); tortilla chips. This industry comprises establishments primarily engaged in one or more of the following: (1) salting, roasting, drying, cooking, or canning nuts; (2) processing grains or seeds into snacks; (3) manufacturing peanut butter; and (4) manufacturing potato chips, corn chips, popped popcorn, pretzels (except soft), pork rinds, and similar snacks.   |
| Coffee and tea                                     | Coffee concentrates (instant coffee); coffee extracts; coffee flavoring and syrups; coffee roasting; coffee substitute; blended coffee; instant and freeze dried coffee; Coffee essences/preparations/extracts; instant coffee; instant tea; roasting coffee; syrup/coffee based flavoring; tea (except herbal); tea blending; herbal tea manufacturing; instant tea manufacturing.  |

|                                     |  |
|-------------------------------------|--|
| Seasonings and dressings            | Cheese based salad dressing; cider vinegar; cider (non-alcoholic); dips (except cheese and sour cream based); horseradish prepared sauce; mayonnaise manufacturing; prepared mustard; prepared sauces (except gravy, tomato based); salad dressings; salad dressing based sandwich spreads; sauces (except tomato); sauces for meat; sauces for seafood; sauces for vegetables; soy sauce; tartar sauce; vinegar; worcestershire sauce; chili pepper or powder; food extracts, malt extracts; flavor extracts; food coloring, fruit extracts; dry gravy mixes; grinding spices; hop extract; malt extract and syrups; pectin; pepper (i.e. spice); dry salad dressing mixes; salt substitute; table salt; dry sauce mixes; seasoning salt; spice grinding and blending; spice mixtures; spices and spice mixes.  |
| All other foods                     | Box lunches (for sale off premises); cut/peeled/sliced fresh carrots; fresh cole slaw; fresh egg noodles; perishable foods prepared and packaged for individual resale; cut/peeled fresh fruit; fresh macaroni; fresh pastas; fresh noodles; fresh pizza; peeled or cut potatoes; perishable meals prepared or packaged for individual sale; fresh or refridgerated salas; fresh sandwiches; tofu; cut or peeled fresh vegetables; almond pastes; baking powder; bread crumbs not made in a bakery; cake frosting; fried chinese noodles; dry cocktail mixes; desiccated and shredded coconut; corn syrups made from purchased sweeteners; drink powder mixes; egg substitutes; processed eggs; cake/pie fillings (except fruit, meat, vegetables), prepared frostings; gelatin dessert preparations; gelatin for cooking; honey processing; maple syrup mixing into other products; noodle mixes made form purchased dry ingredients; friend noodles; pancake syrups (except pure maple); pasta mixes made from dry ingredients; popcorn (except popped); potato mixes made from purchased dry ingredients; potato mixes made from purchased dry ingredients; canned pudding desserts; dessert puddings; rice mixes; soghum syrup; dry soup mixes; sweetening syrups (except pure maple); corn syrup (except wet milled); sweetening syrup (except pure maple); table syrup articially flavored; yeast. |
| Bottled water, soft drinks, and ice | Artificially carbonated waters; fruit/vegetable drinks, cocktails, ades; soft drinks; carbonated soda; carbonated soft drinks; iced coffee; fruit drinks (except juice); flavored water; iced tea; flavored water.   |
| Beer                                | Ale, beer, beer/ale/malt liquor beverages; breweries; lager, malt liquor, near beer; nonalcoholic beer; porter brewing; stout brewing.   |
| Wine                                | Brandy alcoholic beverages; applejack distilling; wine and brandy beverages; blending brandy; blending wines; brandy distilling; champagne method sparkling wine; alcoholic cider; brandy distilling; fortified wines; grape farming and making wine; ice wine; nonalcoholic wines; sparkling wines; vermouth; wine coolers; wineries; wines; cooking wines.   |

|         |  |
|---------|--|
| Spirits | Alcoholic beverages (except brandy); liquor beverages; blending distilled beverages; distilleries; alcoholic eggnog; grain alcohol; ethyl alcohol; mixed drinks; neutral spirits; distilled spirits. |
|---------|--|

## **Appendix B – List of 392 Industries in BEA IO Tables from 2007**

| <b>BEA IO Code</b> | <b>BEA IO Industry/Commodity Description</b>   |
|--------------------|--|
| 1111A0             | Oilseed farming  |
| 1111B0             | Grain farming  |
| 111200             | Vegetable and melon farming  |
| 111300             | Fruit and tree nut farming   |
| 111400             | Greenhouse, nursery, and floriculture production   |
| 111900             | Other crop farming   |
| 1121A0             | Beef cattle ranching and farming, including feedlots and dual-purpose ranching and farming |
| 112120             | Dairy cattle and milk production   |
| 112A00             | Animal production, except cattle and poultry and eggs                                      |
| 112300             | Poultry and egg production   |
| 113000             | Forestry and logging   |
| 114000             | Fishing, hunting and trapping  |
| 115000             | Support activities for agriculture and forestry  |
| 211000             | Oil and gas extraction   |
| 212100             | Coal mining  |
| 2122A0             | Iron, gold, silver, and other metal ore mining   |
| 212230             | Copper, nickel, lead, and zinc mining  |
| 212310             | Stone mining and quarrying   |
| 2123A0             | Other nonmetallic mineral mining and quarrying   |
| 213111             | Drilling oil and gas wells   |
| 21311A             | Other support activities for mining  |
| 221100             | Electric power generation, transmission, and distribution                                  |
| 221200             | Natural gas distribution   |
| 221300             | Water, sewage and other systems  |
| 230301             | Nonresidential maintenance and repair  |
| 230302             | Residential maintenance and repair   |
| 233210             | Health care structures   |
| 233230             | Manufacturing structures   |
| 233240             | Power and communication structures   |
| 233262             | Educational and vocational structures  |
| 233293             | Highways and streets   |
| 2332A0             | Commercial structures, including farm structures   |

|        |  |
|--------|--|
| 2332B0 | Other nonresidential structures  |
| 233411 | Single-family residential structures   |
| 233412 | Multifamily residential structures   |
| 2334A0 | Other residential structures   |
| 321100 | Sawmills and wood preservation   |
| 321200 | Veneer, plywood, and engineered wood product manufacturing                             |
| 321910 | Millwork   |
| 3219A0 | All other wood product manufacturing   |
| 327100 | Clay product and refractory manufacturing  |
| 327200 | Glass and glass product manufacturing  |
| 327310 | Cement manufacturing   |
| 327320 | Ready-mix concrete manufacturing   |
| 327330 | Concrete pipe, brick, and block manufacturing  |
| 327390 | Other concrete product manufacturing   |
| 327400 | Lime and gypsum product manufacturing  |
| 327910 | Abrasive product manufacturing   |
| 327991 | Cut stone and stone product manufacturing  |
| 327992 | Ground or treated mineral and earth manufacturing                                      |
| 327993 | Mineral wool manufacturing   |
| 327999 | Miscellaneous nonmetallic mineral products   |
| 331110 | Iron and steel mills and ferroalloy manufacturing                                      |
| 331200 | Steel product manufacturing from purchased steel                                       |
| 33131A | Alumina refining and primary aluminum production                                       |
| 33131B | Aluminum product manufacturing from purchased aluminum                                 |
| 331411 | Primary smelting and refining of copper  |
| 331419 | Primary smelting and refining of nonferrous metal (except copper and aluminum)         |
| 331420 | Copper rolling, drawing, extruding and alloying  |
| 331490 | Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying |
| 331510 | Ferrous metal foundries  |
| 331520 | Nonferrous metal foundries   |
| 33211A | All other forging, stamping, and sintering   |
| 332114 | Custom roll forming  |
| 33211B | Crown and closure manufacturing and metal stamping                                     |
| 332200 | Cutlery and handtool manufacturing   |
| 332310 | Plate work and fabricated structural product manufacturing                             |
| 332320 | Ornamental and architectural metal products manufacturing                              |
| 332410 | Power boiler and heat exchanger manufacturing  |
| 332420 | Metal tank (heavy gauge) manufacturing   |
| 332430 | Metal can, box, and other metal container (light gauge) manufacturing                  |
| 332500 | Hardware manufacturing   |

|        |  |
|--------|--|
| 332600 | Spring and wire product manufacturing  |
| 332710 | Machine shops  |
| 332720 | Turned product and screw, nut, and bolt manufacturing  |
| 332800 | Coating, engraving, heat treating and allied activities  |
| 33291A | Valve and fittings other than plumbing   |
| 332913 | Plumbing fixture fitting and trim manufacturing  |
| 332991 | Ball and roller bearing manufacturing  |
| 33299A | Ammunition, arms, ordnance, and accessories manufacturing  |
| 332996 | Fabricated pipe and pipe fitting manufacturing   |
| 33299B | Other fabricated metal manufacturing   |
| 333111 | Farm machinery and equipment manufacturing   |
| 333112 | Lawn and garden equipment manufacturing  |
| 333120 | Construction machinery manufacturing   |
| 333130 | Mining and oil and gas field machinery manufacturing   |
| 33329A | Other industrial machinery manufacturing   |
| 333220 | Plastics and rubber industry machinery manufacturing   |
| 333295 | Semiconductor machinery manufacturing  |
| 33331A | Vending, commercial laundry, and other commercial and service industry machinery manufacturing   |
| 333313 | Office machinery manufacturing   |
| 333314 | Optical instrument and lens manufacturing  |
| 333315 | Photographic and photocopying equipment manufacturing  |
| 33341A | Air purification and ventilation equipment manufacturing   |
| 333414 | Heating equipment (except warm air furnaces) manufacturing                                       |
| 333415 | Air conditioning, refrigeration, and warm air heating equipment manufacturing                    |
| 333511 | Industrial mold manufacturing  |
| 33351A | Metal cutting and forming machine tool manufacturing   |
| 333514 | Special tool, die, jig, and fixture manufacturing  |
| 33351B | Cutting and machine tool accessory, rolling mill, and other metalworking machinery manufacturing |
| 333611 | Turbine and turbine generator set units manufacturing  |
| 333612 | Speed changer, industrial high-speed drive, and gear manufacturing                               |
| 333613 | Mechanical power transmission equipment manufacturing  |
| 333618 | Other engine equipment manufacturing   |
| 33391A | Pump and pumping equipment manufacturing   |
| 333912 | Air and gas compressor manufacturing   |
| 333920 | Material handling equipment manufacturing  |
| 333991 | Power-driven handtool manufacturing  |
| 33399A | Other general purpose machinery manufacturing  |
| 333993 | Packaging machinery manufacturing  |
| 333994 | Industrial process furnace and oven manufacturing  |



33399B Fluid power process machinery  
334111 Electronic computer manufacturing  
334112 Computer storage device manufacturing  
33411A Computer terminals and other computer peripheral equipment manufacturing  
334210 Telephone apparatus manufacturing  
334220 Broadcast and wireless communications equipment  
334290 Other communications equipment manufacturing  
334300 Audio and video equipment manufacturing  
33441A Other electronic component manufacturing  
334413 Semiconductor and related device manufacturing  
334418 Printed circuit assembly (electronic assembly) manufacturing  
334510 Electromedical and electrotherapeutic apparatus manufacturing  
334511 Search, detection, and navigation instruments manufacturing  
334512 Automatic environmental control manufacturing  
334513 Industrial process variable instruments manufacturing  
334514 Totalizing fluid meter and counting device manufacturing  
334515 Electricity and signal testing instruments manufacturing  
334516 Analytical laboratory instrument manufacturing  
334517 Irradiation apparatus manufacturing  
33451A Watch, clock, and other measuring and controlling device manufacturing  
334610 Manufacturing and reproducing magnetic and optical media  
335110 Electric lamp bulb and part manufacturing  
335120 Lighting fixture manufacturing  
335210 Small electrical appliance manufacturing  
335221 Household cooking appliance manufacturing  
335222 Household refrigerator and home freezer manufacturing  
335224 Household laundry equipment manufacturing  
335228 Other major household appliance manufacturing  
335311 Power, distribution, and specialty transformer manufacturing  
335312 Motor and generator manufacturing  
335313 Switchgear and switchboard apparatus manufacturing  
335314 Relay and industrial control manufacturing  
335911 Storage battery manufacturing  
335912 Primary battery manufacturing  
335920 Communication and energy wire and cable manufacturing  
335930 Wiring device manufacturing  
335991 Carbon and graphite product manufacturing  
335999 All other miscellaneous electrical equipment and component manufacturing  
336111 Automobile manufacturing  
336112 Light truck and utility vehicle manufacturing

336120 Heavy duty truck manufacturing  
 336211 Motor vehicle body manufacturing  
 336212 Truck trailer manufacturing  
 336213 Motor home manufacturing  
 336214 Travel trailer and camper manufacturing  
 336310 Motor vehicle gasoline engine and engine parts manufacturing  
 336320 Motor vehicle electrical and electronic equipment manufacturing  
 3363A0 Motor vehicle steering, suspension component (except spring), and brake systems manufacturing  
 336350 Motor vehicle transmission and power train parts manufacturing  
 336360 Motor vehicle seating and interior trim manufacturing  
 336370 Motor vehicle metal stamping  
 336390 Other motor vehicle parts manufacturing  
 336411 Aircraft manufacturing  
 336412 Aircraft engine and engine parts manufacturing  
 336413 Other aircraft parts and auxiliary equipment manufacturing  
 336414 Guided missile and space vehicle manufacturing  
 33641A Propulsion units and parts for space vehicles and guided missiles  
 336500 Railroad rolling stock manufacturing  
 336611 Ship building and repairing  
 336612 Boat building  
 336991 Motorcycle, bicycle, and parts manufacturing  
 336992 Military armored vehicle, tank, and tank component manufacturing  
 336999 All other transportation equipment manufacturing  
 337110 Wood kitchen cabinet and countertop manufacturing  
 337121 Upholstered household furniture manufacturing  
 337122 Nonupholstered wood household furniture manufacturing  
 33712A Other household nonupholstered furniture  
 337127 Institutional furniture manufacturing  
 33721A Office furniture and custom architectural woodwork and millwork manufacturing  
 337215 Showcase, partition, shelving, and locker manufacturing  
 337900 Other furniture related product manufacturing  
 339112 Surgical and medical instrument manufacturing  
 339113 Surgical appliance and supplies manufacturing  
 339114 Dental equipment and supplies manufacturing  
 339115 Ophthalmic goods manufacturing  
 339116 Dental laboratories  
 339910 Jewelry and silverware manufacturing  
 339920 Sporting and athletic goods manufacturing  
 339930 Doll, toy, and game manufacturing  
 339940 Office supplies (except paper) manufacturing

|        |   |
|--------|---|
| 339950 | Sign manufacturing  |
| 339990 | All other miscellaneous manufacturing                           |
| 311111 | Dog and cat food manufacturing                                  |
| 311119 | Other animal food manufacturing                                 |
| 311210 | Flour milling and malt manufacturing                            |
| 311221 | Wet corn milling  |
| 31122A | Soybean and other oilseed processing                            |
| 311225 | Fats and oils refining and blending                             |
| 311230 | Breakfast cereal manufacturing                                  |
| 311300 | Sugar and confectionery product manufacturing                   |
| 311410 | Frozen food manufacturing                                       |
| 311420 | Fruit and vegetable canning, pickling, and drying               |
| 31151A | Fluid milk and butter manufacturing                             |
| 311513 | Cheese manufacturing  |
| 311514 | Dry, condensed, and evaporated dairy product manufacturing      |
| 311520 | Ice cream and frozen dessert manufacturing                      |
| 31161A | Animal (except poultry) slaughtering, rendering, and processing |
| 311615 | Poultry processing  |
| 311700 | Seafood product preparation and packaging                       |
| 311810 | Bread and bakery product manufacturing                          |
| 3118A0 | Cookie, cracker, pasta, and tortilla manufacturing              |
| 311910 | Snack food manufacturing  |
| 311920 | Coffee and tea manufacturing                                    |
| 311930 | Flavoring syrup and concentrate manufacturing                   |
| 311940 | Seasoning and dressing manufacturing                            |
| 311990 | All other food manufacturing                                    |
| 312110 | Soft drink and ice manufacturing                                |
| 312120 | Breweries   |
| 312130 | Wineries  |
| 312140 | Distilleries  |
| 312200 | Tobacco product manufacturing                                   |
| 313100 | Fiber, yarn, and thread mills                                   |
| 313200 | Fabric mills  |
| 313300 | Textile and fabric finishing and fabric coating mills           |
| 314110 | Carpet and rug mills  |
| 314120 | Curtain and linen mills   |
| 314900 | Other textile product mills                                     |
| 315000 | Apparel manufacturing   |
| 316000 | Leather and allied product manufacturing                        |
| 322110 | Pulp mills  |

|        |  |
|--------|--|
| 322120 | Paper mills  |
| 322130 | Paperboard mills   |
| 322210 | Paperboard container manufacturing   |
| 322220 | Paper bag and coated and treated paper manufacturing                             |
| 322230 | Stationery product manufacturing   |
| 322291 | Sanitary paper product manufacturing   |
| 322299 | All other converted paper product manufacturing                                  |
| 323110 | Printing   |
| 323120 | Support activities for printing  |
| 324110 | Petroleum refineries   |
| 324121 | Asphalt paving mixture and block manufacturing                                   |
| 324122 | Asphalt shingle and coating materials manufacturing                              |
| 324190 | Other petroleum and coal products manufacturing                                  |
| 325110 | Petrochemical manufacturing  |
| 325120 | Industrial gas manufacturing   |
| 325130 | Synthetic dye and pigment manufacturing  |
| 325180 | Other basic inorganic chemical manufacturing                                     |
| 325190 | Other basic organic chemical manufacturing                                       |
| 325211 | Plastics material and resin manufacturing  |
| 3252A0 | Synthetic rubber and artificial and synthetic fibers and filaments manufacturing |
| 325310 | Fertilizer manufacturing   |
| 325320 | Pesticide and other agricultural chemical manufacturing                          |
| 325411 | Medicinal and botanical manufacturing  |
| 325412 | Pharmaceutical preparation manufacturing   |
| 325413 | In-vitro diagnostic substance manufacturing                                      |
| 325414 | Biological product (except diagnostic) manufacturing                             |
| 325510 | Paint and coating manufacturing  |
| 325520 | Adhesive manufacturing   |
| 325610 | Soap and cleaning compound manufacturing   |
| 325620 | Toilet preparation manufacturing   |
| 325910 | Printing ink manufacturing   |
| 3259A0 | All other chemical product and preparation manufacturing                         |
| 326110 | Plastics packaging materials and unlaminated film and sheet manufacturing        |
| 326120 | Plastics pipe, pipe fitting, and unlaminated profile shape manufacturing         |
| 326130 | Laminated plastics plate, sheet (except packaging), and shape manufacturing      |
| 326140 | Polystyrene foam product manufacturing   |
| 326150 | Urethane and other foam product (except polystyrene) manufacturing               |
| 326160 | Plastics bottle manufacturing  |
| 326190 | Other plastics product manufacturing   |
| 326210 | Tire manufacturing   |

|        |   |
|--------|---|
| 326220 | Rubber and plastics hoses and belting manufacturing                             |
| 326290 | Other rubber product manufacturing  |
| 420000 | Wholesale trade   |
| 441000 | Motor vehicle and parts dealers   |
| 445000 | Food and beverage stores  |
| 452000 | General merchandise stores  |
| 4A0000 | Other retail  |
| 481000 | Air transportation  |
| 482000 | Rail transportation   |
| 483000 | Water transportation  |
| 484000 | Truck transportation  |
| 485000 | Transit and ground passenger transportation                                     |
| 486000 | Pipeline transportation   |
| 48A000 | Scenic and sightseeing transportation and support activities for transportation |
| 492000 | Couriers and messengers   |
| 493000 | Warehousing and storage   |
| 511110 | Newspaper publishers  |
| 511120 | Periodical Publishers   |
| 511130 | Book publishers   |
| 5111A0 | Directory, mailing list, and other publishers                                   |
| 511200 | Software publishers   |
| 512100 | Motion picture and video industries   |
| 512200 | Sound recording industries  |
| 515100 | Radio and television broadcasting   |
| 515200 | Cable and other subscription programming  |
| 517110 | Wired telecommunications carriers   |
| 517210 | Wireless telecommunications carriers (except satellite)                         |
| 517A00 | Satellite, telecommunications resellers, and all other telecommunications       |
| 518200 | Data processing, hosting, and related services                                  |
| 5191A0 | News syndicates, libraries, archives and all other information services         |
| 519130 | Internet publishing and broadcasting and Web search portals                     |
| 52A000 | Monetary authorities and depository credit intermediation                       |
| 522A00 | Nondepository credit intermediation and related activities                      |
| 523A00 | Securities and commodity contracts intermediation and brokerage                 |
| 523900 | Other financial investment activities   |
| 524100 | Insurance carriers  |
| 524200 | Insurance agencies, brokerages, and related activities                          |
| 525000 | Funds, trusts, and other financial vehicles                                     |
| 5310HS | Housing   |
| 5310RE | Other real estate   |

|        |   |
|--------|---|
| 532100 | Automotive equipment rental and leasing   |
| 532A00 | Consumer goods and general rental centers   |
| 532400 | Commercial and industrial machinery and equipment rental and leasing                            |
| 533000 | Lessors of nonfinancial intangible assets   |
| 541100 | Legal services  |
| 541511 | Custom computer programming services  |
| 541512 | Computer systems design services  |
| 54151A | Other computer related services, including facilities management                                |
| 541200 | Accounting, tax preparation, bookkeeping, and payroll services                                  |
| 541300 | Architectural, engineering, and related services  |
| 541400 | Specialized design services   |
| 541610 | Management consulting services  |
| 5416A0 | Environmental and other technical consulting services   |
| 541700 | Scientific research and development services  |
| 541800 | Advertising, public relations, and related services   |
| 5419A0 | Marketing research and all other miscellaneous professional, scientific, and technical services |
| 541920 | Photographic services   |
| 541940 | Veterinary services   |
| 550000 | Management of companies and enterprises   |
| 561100 | Office administrative services  |
| 561200 | Facilities support services   |
| 561300 | Employment services   |
| 561400 | Business support services   |
| 561500 | Travel arrangement and reservation services   |
| 561600 | Investigation and security services   |
| 561700 | Services to buildings and dwellings   |
| 561900 | Other support services  |
| 562000 | Waste management and remediation services   |
| 611100 | Elementary and secondary schools  |
| 611A00 | Junior colleges, colleges, universities, and professional schools                               |
| 611B00 | Other educational services  |
| 621100 | Offices of physicians   |
| 621200 | Offices of dentists   |
| 621300 | Offices of other health practitioners   |
| 621400 | Outpatient care centers   |
| 621500 | Medical and diagnostic laboratories   |
| 621600 | Home health care services   |
| 621900 | Other ambulatory health care services   |
| 622000 | Hospitals   |
| 623A00 | Nursing and community care facilities   |

|        |   |
|--------|---|
| 623B00 | Residential mental retardation, mental health, substance abuse and other facilities   |
| 624100 | Individual and family services  |
| 624A00 | Community food, housing, and other relief services, including rehabilitation services |
| 624400 | Child day care services   |
| 711100 | Performing arts companies   |
| 711200 | Spectator sports  |
| 711A00 | Promoters of performing arts and sports and agents for public figures                 |
| 711500 | Independent artists, writers, and performers  |
| 712000 | Museums, historical sites, zoos, and parks  |
| 713100 | Amusement parks and arcades   |
| 713200 | Gambling industries (except casino hotels)  |
| 713900 | Other amusement and recreation industries   |
| 721000 | Accommodation   |
| 722110 | Full-service restaurants  |
| 722211 | Limited-service restaurants   |
| 722A00 | All other food and drinking places  |
| 811100 | Automotive repair and maintenance   |
| 811200 | Electronic and precision equipment repair and maintenance                             |
| 811300 | Commercial and industrial machinery and equipment repair and maintenance              |
| 811400 | Personal and household goods repair and maintenance                                   |
| 812100 | Personal care services  |
| 812200 | Death care services   |
| 812300 | Dry-cleaning and laundry services   |
| 812900 | Other personal services   |
| 813100 | Religious organizations   |
| 813A00 | Grantmaking, giving, and social advocacy organizations                                |
| 813B00 | Civic, social, professional, and similar organizations                                |
| 814000 | Private households  |
| S00500 | Federal general government (defense)  |
| S00600 | Federal general government (nondefense)   |
| 491000 | Postal service  |
| S00102 | Other federal government enterprises  |
| S00700 | State and local general government  |
| S00203 | Other state and local government enterprises  |
| S00401 | Scrap   |
| S00402 | Used and secondhand goods   |
| S00300 | Noncomparable imports   |
| S00900 | Rest of the world adjustment  |
| V00100 | Compensation of employees   |
| V00200 | Taxes on production and imports, less subsidies                                       |

**Appendix C – Industry and commodity specific price indices**

| <b>BEA IO code</b> | <b>BEA IO industry description</b>                              | <b>Inflation index<br/>(2007/2012-2013)</b> |
|--------------------|---|---|
| 111200             | Vegetable and melon farming                                     | 1.0281                                      |
| 111300             | Fruit and tree nut farming                                      | 1.2609                                      |
| 112300             | Poultry and egg production                                      | 1.2103                                      |
| 311210             | Flour milling and malt manufacturing                            | 1.3573                                      |
| 311221             | Wet corn milling  | 1.3594                                      |
| 31122A             | Soybean and other oilseed processing                            | 1.5962                                      |
| 311225             | Fats and oils refining and blending                             | 1.4059                                      |
| 311230             | Breakfast cereal manufacturing                                  | 1.1693                                      |
| 311300             | Sugar and confectionery product manufacturing                   | 1.2963                                      |
| 311410             | Frozen food manufacturing                                       | 1.1947                                      |
| 311420             | Fruit and vegetable canning, pickling, and drying               | 1.2150                                      |
| 31151A             | Fluid milk and butter manufacturing                             | 1.1074                                      |
| 311513             | Cheese manufacturing  | 1.0971                                      |
| 311514             | Dry, condensed, and evaporated dairy product manufacturing      | 1.0830                                      |
| 311520             | Ice cream and frozen dessert manufacturing                      | 1.1870                                      |
| 31161A             | Animal (except poultry) slaughtering, rendering, and processing | 1.3473                                      |
| 311615             | Poultry processing  | 1.2026                                      |
| 311700             | Seafood product preparation and packaging                       | 1.2260                                      |
| 311810             | Bread and bakery product manufacturing                          | 1.2680                                      |
| 3118A0             | Cookie, cracker, pasta, and tortilla manufacturing              | 1.2270                                      |
| 311910             | Snack food manufacturing  | 1.3191                                      |
| 311920             | Coffee and tea manufacturing                                    | 1.2402                                      |
| 311930             | Flavoring syrup and concentrate manufacturing                   | 1.0615                                      |
| 311940             | Seasoning and dressing manufacturing                            | 1.1732                                      |
| 311990             | All other food manufacturing                                    | 1.1574                                      |
| 312110             | Soft drink and ice manufacturing                                | 1.1258                                      |
| 312120             | Breweries   | 1.2024                                      |
| 312130             | Wineries  | 1.0481                                      |
| 312140             | Distilleries  | 1.0810                                      |
| 420000             | Wholesale trade   | 1.1072                                      |
| 445000             | Food and beverage stores  | 1.1677                                      |
| 452000             | General merchandise stores                                      | 1.1679                                      |
| 453000             | Misc. store retailers   | 1.0889                                      |



|        |                                    |        |
|--------|------------------------------------|--------|
| 481000 | Air transportation                 | 1.2458 |
| 482000 | Rail transportation                | 1.2727 |
| 483000 | Water transportation               | 1.0360 |
| 484000 | Truck transportation               | 1.1393 |
| 722110 | Full-service restaurants           | 1.1579 |
| 722211 | Limited-service restaurants        | 1.1656 |
| 722A00 | All other food and drinking places | 1.1624 |

## Appendix D – FNDDS WWEIA food categories and sub-categories

### 1 Milk and Milk Products

#### 11 Milks and milk drinks

- 110 Milk, human
- 111 Milk, fluid (regular; filled; buttermilk; and dry reconstituted)
- 112 Milk, fluid, evaporated and condensed
- 113 Milk, fluid, imitation
- 114 Yogurt 1148 Yogurt, baby food
- 115 Flavored milk and milk drinks, fluid
- 117 Infant formulas, fluid, reconstituted concentrate, reconstituted dry, and ready-to-feed (milk-based formulas; soy-based formulas; therapeutic formulas)
- 118 Milk, dry, and powdered mixtures with dry milk, not reconstituted

#### 12 Creams and cream substitutes

- 121 Sweet dairy cream
- 122 Cream substitutes
- 123 Sour cream

#### 13 Milk desserts, sauces, gravies

- 131 Milk desserts, frozen
- 132 Puddings, custards, and other milk desserts
- 133 Milk desserts baby food
- 134 White sauces and milk gravies

#### 14 Cheeses

- 140 Cheese, NS as to type
- 141 Natural cheese
- 142 Cottage cheeses
- 143 Cream cheese
- 144 Processed cheese and cheese spreads
- 145 Imitation cheese
- 146 Cheese mixtures
- 147 Cheese soups

### 2 Meat, Poultry, Fish, and Mixtures

#### 20 Meat, NS as to type

200 Meat, NS as to type

#### 21 Beef

- 210 Beef, NFS
- 211 Beef steak
- 213 Beef oxtails, neckbones, short ribs, head
- 214 Beef roasts, stew meat, corned beef, beef brisket, sandwich steaks
- 215 Ground beef, beef patties, beef meatballs

- 216 Other beef items (beef bacon; dried beef; pastrami)
- 217 Beef baby food

**22 Pork**

- 220 Pork, NFS; ground, dehydrated
- 221 Pork chops
- 222 Pork steaks, cutlets
- 223 Ham
- 224 Pork roasts
- 225 Canadian bacon
- 226 Bacon, salt pork
- 227 Other pork items (spareribs; cracklings; skin; miscellaneous parts)
- 228 Pork baby food

**23 Lamb, veal, game, other carcass meat**

- 230 Lamb, NFS
- 231 Lamb and goat
- 232 Veal
- 233 Game
- 234 Lamb or veal baby food

**24 Poultry**

- 241 Chicken (breast; leg; drumstick; wing; back; neck or ribs; misc)
- 242 Turkey
- 243 Duck
- 244 Other poultry
- 247 Poultry baby food

**25 Organ meats, sausages and lunchmeats, and meat spreads**

- 251 Organ meats and mixtures 2511 Liver
- 2512 Hearts 2513 Kidney 2514 Sweetbreads 2515 Brains
- 2516 Tongue
- 2517 Other variety meats 252 Frankfurters, sausages, lunchmeats, meat spreads
- 2521 Frankfurters 2522 Sausages 2523 Luncheon meats (loaf) 2524 Potted meat, spreads

**26 Fish and shellfish 261 Finfish**

- 262 Other seafood
- 263 Shellfish

**27 Meat, poultry, fish with nonmeat items**

- 271 Meat, poultry, fish in gravy or sauce or creamed
  - 2711 Beef in gravy or sauce (tomato-based sauce; gravy; cream, white, or soup-based sauce; soy-based sauce; other sauce; Puerto Rican)
  - 2712 Pork with gravy or sauce
  - 2713 Lamb and veal with gravy or sauce
  - 2714 Poultry with gravy or sauce (tomato-based sauce; gravy; cream, white, or soup-based sauce; soy-based sauce; other sauces; Puerto Rican)
  - 2715 Fish, shellfish with gravy or sauce
  - 2716 Miscellaneous meats with gravy or sauce
- 272 Meat, poultry, fish with starch item (includes white potatoes)
  - 2721 Beef with starch item (potatoes; noodles; rice; bread; Puerto Rican)
  - 2722 Pork with starch item
  - 2723 Lamb, veal, game with starch item
  - 2724 Poultry with starch item (potatoes; noodles; rice; bread)
  - 2725 Fish, shellfish with starch item
  - 2726 Miscellaneous meats with starch item
- 273 Meat, poultry, fish with starch item and vegetables

- 2731 Beef with starch and vegetable (potatoes; noodles; rice; bread; Puerto Rican)
- 2732 Pork with starch and vegetable
- 2733 Lamb, veal, game with starch and vegetable
- 2734 Poultry with starch and vegetable (potatoes; noodles; rice; bread; Puerto Rican)
- 2735 Fish, shellfish with starch and vegetable
- 2736 Miscellaneous meats with starch and vegetable
- 274 Meat, poultry, fish with vegetables (excluding white potatoes)
  - 2741 Beef with vegetable, no potatoes
  - 2742 Pork with vegetable, no potatoes
  - 2743 Lamb, veal, game with vegetable, no potatoes
  - 2744 Poultry with vegetables, no potatoes
  - 2745 Fish, shellfish with vegetables, no potatoes 62
  - 2746 Miscellaneous meats with vegetable, no potatoes
- 275 Sandwiches with meat, poultry, fish 2751 Beef sandwiches 2752 Pork sandwiches 2754 Poultry sandwiches 2755 Fish, shellfish sandwiches 2756 Frankfurters, luncheon meat, potted meat sandwiches 2757 Hors d'oeuvres, finger sandwiches
- 276 Meat, poultry, fish with nonmeat items baby food 2761 Beef mixtures baby food 2764 Poultry mixtures baby food
- 28 Frozen and shelf-stable plate meals, soups, and gravies with meat, poultry, fish base; gelatin and gelatin-based drinks**
  - 281 Frozen or shelf-stable plate meals with meat, poultry, fish as major ingredient
    - 2811 Beef frozen or shelf-stable meals 2813 Veal frozen or shelf-stable meals 2814 Poultry frozen or shelf-stable meals 2815 Fish, shellfish frozen meals
    - 2816 Miscellaneous meat frozen or shelf-stable meals 283 Soups, broths, extracts from meat, poultry, fish base
    - 2831 Beef soups
    - 2832 Pork soups
    - 2833 Lamb soups
    - 2834 Poultry, soups
    - 28345 Poultry cream soups
    - 2835 Fish, shellfish soups
    - 2836 Puerto Rican soups
  - 284 Gelatin and gelatin-based meal supplements
  - 285 Gravies from meat, poultry, fish base
- 3 Eggs**
- 31 Eggs**
  - 311 Chicken eggs
  - 312 Other poultry eggs
- 32 Egg mixtures**
  - 321 Egg dishes (mixtures made with whole eggs)
  - 322 Egg sandwiches
  - 323 Egg soups
  - 324 Mixtures made with egg whites
- 33 Egg substitutes**
  - 330 Egg substitute, NS as to form
  - 334 Mixtures made with egg substitutes
- 35 Frozen plate meals with egg as major ingredient**
  - 350 Frozen plate meals with egg as major ingredient
- 4 Dry Beans, Peas, Other Legumes, Nuts, and Seeds**
- 41 Legumes**
  - 411 Dried beans
  - 412 Dried beans mixtures

- 413 Dried peas, lentils, and mixtures
- 414 Soybean derived products (excluding milks)
- 416 Soups with legumes as major ingredient
- 418 Meat substitutes, mainly legume protein
- 419 Meat substitute sandwiches
- 42 Nuts, nut butters, and nut mixtures**
  - 421 Nuts
  - 422 Nut butters
  - 423 Nut butter sandwiches
  - 424 Coconut beverages
  - 425 Nut mixtures
- 43 Seeds and seed mixtures** 431 Seeds
- 44 Carob products**
  - 441 Carob powder, flour
  - 442 Carob chips, syrup
- 5 Grain Products**
- 50 Flour and dry mixes**
  - 500 Flour and dry mixes
- 51 Yeast breads, rolls**
  - 510 Breads, rolls, NFS
  - 511 White breads, rolls
  - 512 Whole wheat breads, rolls
  - 513 Wheat, cracked wheat breads, rolls
  - 514 Rye breads, rolls
  - 515 Oat breads
  - 516 Multigrain breads, rolls
  - 518 Other breads
- 52 Quick breads**
  - 521 Biscuits
  - 522 Cornbread, corn muffins, tortillas
  - 523 Other muffins, popovers
  - 524 Other quick breads
- 53 Cakes, cookies, pies, pastries, bars**
  - 531 Cakes
  - 532 Cookies
  - 533 Pies (fruit pies; pie tarts; cream and custard pies; miscellaneous pies; pie shells)
  - 534 Cobblers, eclairs, turnovers, other pastries
  - 535 Danish, breakfast pastries, doughnuts
  - 536 Coffee cake, not yeast
  - 537 Bars
    - 5371 Cereal bars, granola bars
    - 5372 Nutrition bars (protein, energy, meal replacement, etc)
  - 538 Cookies and bars, baby food
- 54 Crackers and salty snacks from grain products**
  - 540 Crackers, NS as to type
  - 541 Sweet crackers
  - 542 Low sodium crackers
  - 543 Nonsweet crackers
  - 544 Salty snacks from grain products
- 55 Pancakes, waffles, French toast, other grain products**
  - 551 Pancakes

- 552 Waffles
- 553 French toast
- 554 Crepes
- 555 Flour-water patties
- 556 Flour-milk dumplings, plain
- 557 Rice flour cakes
- 558 Funnel cakes
- 56 Pastas, cooked cereals, rice**
  - 561 Pastas
  - 562 Cooked cereals, rice
- 57 Cereals, not cooked or NS as to cooked**
  - 570 Cereal, NS as to cooked
  - 571 Ready-to-eat cereals
  - 572 Ready-to-eat cereals
  - 573 Ready-to-eat cereals
  - 574 Ready-to-eat cereals
  - 576 Cereal grains, not cooked
  - 578 Cereals baby food
- 58 Grain mixtures, frozen plate meals, soups**
  - 581 Mixtures, mainly grain, pasta, or bread
  - 582 Mixtures, mainly grain, pasta, or bread
  - 583 Frozen plate meals with grain mixture as major ingredient
  - 584 Soups with grain product as major ingredient
  - 585 Grain mixtures baby food
- 59 Meat substitutes, mainly cereal protein**
  - 590 Meat substitutes, mainly cereal protein
- 6 Fruits**
  - 61 Citrus fruits, juices**
    - 611 Citrus fruits
    - 612 Citrus fruit juices
  - 62 Dried fruits**
    - 621 Dried fruits
  - 63 Other fruits**
    - 631 Fruits, excluding berries
    - 632 Berries
    - 633 Mixtures of two or more fruits
    - 634 Mixtures of fruits and nonfruit items
  - 64 Fruit juices and nectars excluding citrus**
    - 641 Fruit juices, excluding citrus
    - 642 Nectars
    - 644 Vinegar
  - 67 Fruits and juices baby food**
    - 671 Fruits and fruit mixtures baby food
    - 672 Fruit juice and fruit juice mixtures baby food
    - 673 Fruits with cereal baby food
    - 674 Fruit desserts and fruit-flavored puddings and yogurt desserts baby food
    - 675 Fruits with meat or poultry baby food
    - 676 Fruits and vegetables mixtures baby food
- 7 Vegetables**
  - 71 White potatoes and Puerto Rican starchy vegetables**
    - 710 White potatoes, NFS
    - 711 White potatoes, baked and boiled
    - 712 White potatoes, chips and sticks

- 713 White potatoes, creamed, scalloped, au gratin
- 714 White potatoes, fried
- 715 White potatoes, mashed, stuffed, puffs
- 716 Potato salad
- 717 Potato recipes
- 718 Potato soups
- 719 Puerto Rican starchy vegetables
- 72 Dark-green vegetables**
  - 721 Dark-green leafy vegetables
  - 722 Dark-green nonleafy vegetables
  - 723 Dark-green vegetable soups
- 73 Deep-yellow vegetables**
  - 731 Carrots
  - 732 Pumpkin
  - 733 Squash, winter
  - 734 Sweet potatoes
  - 735 Deep-yellow vegetable soups
- 74 Tomatoes and tomato mixtures**
  - 741 Tomatoes, raw
  - 742 Tomatoes, cooked
  - 743 Tomato juices
  - 744 Tomato sauces
  - 745 Tomato mixtures
  - 746 Tomato soups
  - 747 Tomato sandwiches
- 75 Other vegetables**
  - 751 Other vegetables, raw 7514 Raw vegetable mixtures
  - 752 Other vegetables, cooked
  - 753 Other vegetable mixtures, cooked
  - 754 Other cooked vegetables, cooked with sauces, batters, casseroles
  - 755 Olives, pickles, relishes (excluding tomatoes)
  - 756 Vegetable soups
- 76 Vegetables and mixtures mostly vegetables baby food**
  - 761 Dark-green vegetables baby food
  - 762 Deep-yellow vegetables baby food
  - 764 Vegetables other than dark-green, deep-yellow, and tomato baby food
  - 765 Vegetables with grain baby food
  - 766 Vegetables with meat baby food
- 77 Vegetables with meat, poultry, fish**
  - 771 White potato with meat, poultry, fish (mixtures)
  - 772 Puerto Rican starchy vegetable (viandas) mixtures
  - 773 Other vegetable mixtures
  - 775 Puerto Rican stews or soups with starchy vegetables (viandas)
- 78 Mixtures mostly vegetables without meat, poultry, fish**
  - 781 Vegetable and fruit juice blends, 100% juice
- 8 Fats, Oils, and Salad Dressings**
- 81 Fats**
  - 811 Table fats
  - 812 Cooking fats
  - 813 Other fats
- 82 Oils**

- 821 Vegetable oils
- 83 Salad dressings**
  - 831 Regular salad dressings
  - 832 Light salad dressings
  - 833 Fat free salad dressings
- 9 Sugars, Sweets, and Beverages**
  - 91 Sugars and sweets**
    - 911 Sugars and sugar-sugar substitute blends
    - 912 Sugar replacements or substitute
    - 913 Syrups, honey, molasses, sweet toppings
    - 914 Jellies, jams, preserves
    - 915 Gelatin desserts or salads
    - 916 Ices or popsicles
    - 917 Candies
    - 918 Chewing gums
  - 92 Nonalcoholic beverages**
    - 921 Coffee
    - 922 Coffee substitutes
    - 923 Tea
    - 924 Soft drinks, carbonated
    - 925 Fruit drinks
      - 9251 Fruit juice drinks and fruit-flavored drinks
      - 9253 Fruit juice drinks and fruit flavored drinks with high vitamin C
      - 9254 Fruit flavored drinks, made from powdered mix
      - 9255 Fruit juice drinks and fruit flavored drinks, low calorie
      - 9258 Fruit juice drinks and fruit flavored drinks, fortified with calcium
    - 926 Beverages, nonfruit
    - 928 Nonalcoholic beers, wines, cocktails
    - 929 Beverage concentrates, dry, not reconstituted
  - 93 Alcoholic beverages**
    - 931 Beers and ales
    - 932 Cordials and liqueurs
    - 933 Cocktails
    - 934 Wines
    - 935 Distilled liquors
  - 94 Water, noncarbonated**
    - 940 Water, not bottled
    - 941 Water, bottled
    - 942 Water, bottled, fortified
    - 943 Water, baby food
  - 95 Formulated nutrition beverages, energy drinks, sports drinks, functional beverages**
    - 951 Nutrition drinks 952 Nutrition powders
    - 9531 Energy drinks
    - 9532 Sports drinks
    - 9533 Fluid replacements
    - 9534 Other functional beverages

**Appendix E – FPID food categories and sub-categories**

| <b>FPID code</b> | <b>FPID group description</b>       |
|------------------|-------------------------------------|
| 100              | Dairy and egg products              |
| 200              | Spices and herbs                    |
| 300              | Baby foods                          |
| 400              | Fats and oils                       |
| 500              | Poultry products                    |
| 600              | Soups, sauces, and gravies          |
| 700              | Sausages and luncheon meats         |
| 800              | Breakfast cereals                   |
| 900              | Fruits and fruit juices             |
| 1000             | Pork products                       |
| 1100             | Vegetables and vegetable products   |
| 1200             | Nut and seed products               |
| 1300             | Beef products                       |
| 1400             | Beverages                           |
| 1500             | Finfish and shellfish products      |
| 1600             | Legumes and legume products         |
| 1700             | Lamb, veal, and game products       |
| 1800             | Baked products                      |
| 1900             | Sweets                              |
| 2000             | Cereal grains and pasta             |
| 2100             | Fast foods                          |
| 2200             | Meals, entrees, and side dishes     |
| 2500             | Snacks                              |
| 3500             | American Indian/Alaska Native Foods |
| 3600             | Restaurant foods                    |



