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Food-Miles and the Relative Climate Impacts of Food Choices in the United States

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Despite significant recent public concern and media attention to the environmental impacts of food, few studies in the United States have systematically compared the life-cycle greenhouse gas (GHG) emissions associated with food production against long-distance distribution, aka "food-miles." We find that although food is transported long distances in general (1640 km delivery and 6760 km life-cycle supply chain on average) the GHG emissions associated with food are dominated by the production phase, contributing 83% of the average U.S. household's 8.1 t CO_2e/yr footprint for food consumption. Transportation as a whole represents only 11% of life-cycle GHG emissions, and final delivery from producer to retail contributes only 4%. Different food groups exhibit a large range in GHG-intensity; on average, red meat is around 150% more GHG-intensive than chicken or fish. Thus, we suggest that dietary shift can be a more effective means of lowering an average household's food-related climate footprint than "buying local." Shifting less than one day per week's worth of calories from red meat and dairy products to chicken, fish, eggs, or a vegetable-based diet achieves more GHG reduction than buying all locally sourced food.

Introduction

With growing public concern over climate change, information and opportunities for consumers to lower their "carbon footprint," a measure of the total consumer responsibility for greenhouse gas emissions, have become increasingly available. The growing field of sustainable consumption (*1*−*3*) has offered information to consumers on the climate and environmental impacts of their consumptive choices. In general, much of this research has concluded that food, home energy, and transportation together form a large share of most consumers' personal impacts (*2*).

Of these three, food represents a unique opportunity for consumers to lower their personal impacts due to its high impact, high degree of personal choice, and a lack of long-term "lock-in" effects which limit consumers' day-to-day choices (*1*).

Within the field of consumer food choice, several recent trends associated with environmental sustainability have occurred. The continually increasing penetration of both organic and locally grown food in the U.S. and EU shows that consumers are taking more notice in both how their food is produced and where it comes from. The issue of "food-miles", roughly a measure of how far food travels between its production and the final consumer, has been a consistent fixture in the debate on food sustainability since an initial report from the UK coined the term in 1995 (*4*−*8*). The focus on increased food-miles due to increased international trade in food has led many environmental advocates, retailers, and others to urge a "localization" of the global food supply network (*9*), though many have questioned the legitimacy of this because of different production practices in different regions or the increased storage needed to "buy locally" through all seasons (*6*−*8*). Other advocates, pointing to research on the environmental effects of livestock production (*10*), have urged consumers to shift dietary habits toward vegetable-based diets (*11*).

Food has long held a prominent place in the life-cycle assessment (LCA) literature due to its relative importance for many environmental problems (*11*−*13*). Because of the raw number of foods consumers eat, most analyses have been limited to detailed case studies of either a single food item (*8, 9*) or a limited set of items (*7, 13*), though usually to a higher level of detail than is possible for large groups of products. A few studies exist which look at overall diet (*11, 12*) but even these have usually been limited by availability of life-cycle inventory data for all products. Further, many of the analyses have used life-cycle energy use as the relevant measure of sustainability, and thus they have not included the substantial non-CO_2 greenhouse gas (GHG) emissions associated with agriculture (*8*−*10*). Finally, despite the attention food-miles and transport have gotten in the literature, very few studies have analyzed transportation upstream of the farm (e.g., transport of farm equipment and supplies to the farm), which may be important for life-cycle GHG emissions.

This analysis adds to the existing literature by considering the total life-cycle GHG emissions associated with the production, transportation, and distribution of food consumed by American households. We include all upstream impacts using input−output life-cycle assessment (IO-LCA), analyze all food and nonalcoholic beverages, and include all relevant emissions of greenhouse gases in the supply chains of food products. Several uncertainties, discussed below, complicate attempts to make definitive claims of superiority, and results from such a holistic assessment will necessarily be averaged and context-specific. Nonetheless, by using such a holistic assessment of climate impacts from both transportation and production of food, we hope to inform the ongoing debate on the relative climate impacts of "food-miles" and dietary choices. The next section describes the methods utilized in the analysis, followed by a summary of the results obtained (full results are available in the Supporting Information), and a discussion of the results.

Methods and Data

The method utilized is input−output life-cycle assessment (IO-LCA) (*14, 15*). IO-LCA has several advantages for such an analysis, such as being able to handle large bundles of goods as well as reducing cutoff error, one of the major drawbacks of process-based LCA (*16*). IO-LCA has its drawbacks as well—aggregation in economic sectors is a significant problem—but it is ideal for analysis of large groups of products from a scoping perspective.

A detailed model development is presented in the Supporting Information and is summarized here. As originally formalized by Leontief in his groundbreaking work in the 1930s (*15*), the total output of an economy, **x**, can be expressed

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as the sum of intermediate consumption, **Ax**, and final consumption, **y**, as follows:

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y} \quad (1)$$

where **A** is the economy's direct requirements matrix. When solved for total output, **x**, this equation yields

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\,\mathbf{y} \quad (2)$$

As shown previously (*17*), the direct requirements matrix can be derived in a number of different ways. In general, the industry-by-commodity matrix, denoted here $\mathbf{A}_{I\times C}$, is seen as the most useful form of the direct requirements matrix, **A**, or the Leontief inverse, $(\mathbf{I} - \mathbf{A})^{-1} = \mathbf{L}_{I\times C}$, since it allows the input of a final demand of commodities and a supply chain of industrial output, which can easily be converted to emissions using a coupled emissions vector, $\mathbf{F} = \mathbf{x}^{-1}\mathbf{f}$, where **f** is the total sectoral emissions of a pollutant

$$\mathbf{f} = \mathbf{F}\mathbf{L}_{I\times C}\mathbf{y}_C \quad (3)$$

If $\mathbf{y}_c$, the commodity final demand, is valued in purchaser, e.g., retail, prices, the retail/wholesale markups and final transportation costs can be distributed using a commodity-by-commodity purchaser−producer price transformation matrix, **T** (*3*)

$$\mathbf{f} = \mathbf{F}\mathbf{L}_{I\times C}\mathbf{T}\mathbf{y}_C \quad (4)$$

This discussion has so far assumed that the relevant emissions/impact data for the calculation is in terms of emissions per industrial output, as is standard in IO-LCA (*18*). However, to model the transportation of goods, a commodity-by-commodity model ($\mathbf{A}_{C\times C}$, $\mathbf{L}_{C\times C}$) would be more appropriate, with impacts measured in terms of t-km moved per commodity purchased rather than per industrial output. We denote this matrix of modal t-km moved per commodity output as $\mathbf{F}_{tkm}$ = total t-km, by mode, moved by each commodity, divided by total commodity output. Data on domestic t-km moved by commodities was taken from the 1997 U.S. Commodity Flow Survey (CFS) (*19*), which was mapped to the input−output commodity groups from the 1997 benchmark input−output model of the United States (*20*), the most recent such model available for the U.S. Ton-km moved by international water and air transport, which are not included in the U.S. CFS, were included in the calculation using U.S. import statistics, which give data on mass of commodity, U.S. port of entry, and exporting country (*21*). The model assumes that all users of a commodity (both final users like households and intermediate users like industries) require the same amount of t-km per dollar purchase of the commodity. On average, the total t-km, by mode, required to deliver a final demand $\mathbf{y}_c$ can be derived as

$$\mathbf{f}_{tkm} = \mathbf{F}_{tkm}\mathbf{L}_{C\times C}\mathbf{T}\mathbf{y}_c \quad (5)$$

Several further steps are necessary to complete and balance the economic portion of the model. See the Supporting Information for details.

Assuming a standard energy intensity of transport per mode, the t-km results can be converted to energy terms, and carbon intensities of fuels from the U.S. EPA (*22*) can further be used to convert to units of t CO_2e/\$ commodity output. Energy intensities per t-km by transport mode were taken predominantly from the U.S. Transportation Energy Data Book (*23*), though data were supplemented from the GREET model (*24*) and literature (*25, 26*) for air freight and international water freight. The assumed energy and carbon intensities of each type of transport are given in Table 1. Note that the carbon intensity of gas pipelines includes U.S. government estimates of methane leakage through transport, explaining its high relative GHG-intensity.

TABLE 1. Energy and Greenhouse Gas Emissions Per ton-km for Different Modes of Transport[a]

	MJ/t-km	t CO_2e/t-km × 10^6	source
inland water	0.3	21	(*23*)
rail	0.3	18	(*23*)
truck	2.7	180	(*23*)
air[a]	10.0	680[a]	(*25*)
oil pipeline	0.2	16	(*23,24*)
gas pipeline	1.7	180	(*23,24*)
int. air[a]	10.0	680[a]	(*25*)
int. water container	0.2	14	(*26*)
int. water bulk	0.2	11	(*26*)
int. water tanker	0.1	7	(*26*)

[a] CO_2 emissions were used as an indicator for the radiative forcing effects of aviation, which are actually higher than just CO_2 emissions (*27*).

In order to compare the GHG emissions associated with freight transport with those associated with production of food, the commodity-based model must be extended to an industry-based model typical of IO-LCA. Thus, the commodity-based final demand from above, $\mathbf{y}_c$, must be converted to industry output using the normalized make matrix, **W**, and multiplied by the industry-based production-related GHG vector, **F** = CO_2e/\$M (*28*)

$$\mathbf{f} = \mathbf{F}\mathbf{W}\mathbf{L}_{C\times C}\mathbf{T}\mathbf{y}_c \quad (6)$$

where emissions from sectors that provide freight transportation have been set to zero to avoid double-counting with the t-km based GHG emissions derived in eq 6. However, this also removes all passenger transportation purchased in these sectors, which were added back in extraneously (see Supporting Information). The GHG emissions vector for production-related emissions was taken from the EIO-LCA model, and its public data sources have been described previously (*18*).

Data on food consumption by households were taken from two main sources: the benchmark U.S. input−output accounts for total economy-wide household expenditure on food (*20*) and food availability statistics from the U.S. Department of Agriculture for household caloric consumption of food (*29*). The commodity groupings were not perfectly interchangeable between the two data sets since the expenditure data are collected on the basis of retail food items (including restaurants and processed/frozen food) while the availability data are collected on the basis of food inputs to retail items (i.e., total meat, total grains, etc.). Thus for some comparisons below, it was assumed that restaurants and processed foods contained the same caloric ratios of primary food groups as the primary food groups themselves (see Supporting Information). Economy-wide and per-capita data were normalized to the common unit of household using data from the U.S. Census on total population and number of households in the U.S. in 1997, approximately 101 million households and 267 million residents (*30*).

Results

Total freight t-km from production to retail to meet food demand in the United States in 1997 were approximately 1.2 × 10^{12} t-km, or when normalized to the 101 million households in the U.S. in 1997, around 12 000 t-km/household/yr (all tons are metric tons, t or tonne). It should be noted that this figure does not include consumer transport to and from retail stores, which is both outside the scope of this study and complicated by multipurpose trips (*8, 31, 32*).

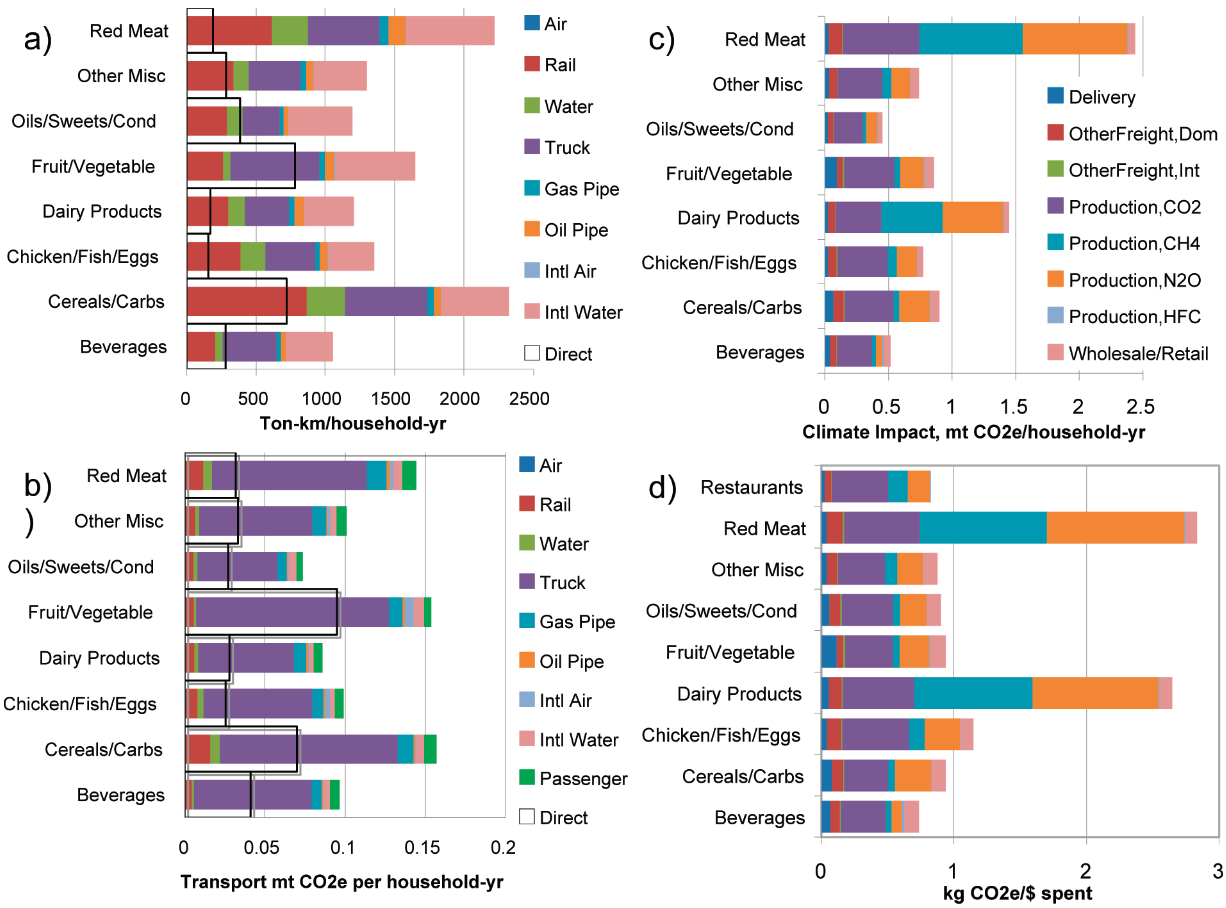

FIGURE 1. Total t-km of freight by mode per year per household (a), transport-related GHG emissions by mode (b), total GHG emissions by supply chain tier (c) associated with household food consumption in the United States, and comparative climate impacts of different food groups (d). The clear boxes (direct in panes a and b) represent final delivery portion of transport chain. Food groups are aggregates of 50 commodities (see Supporting Information).

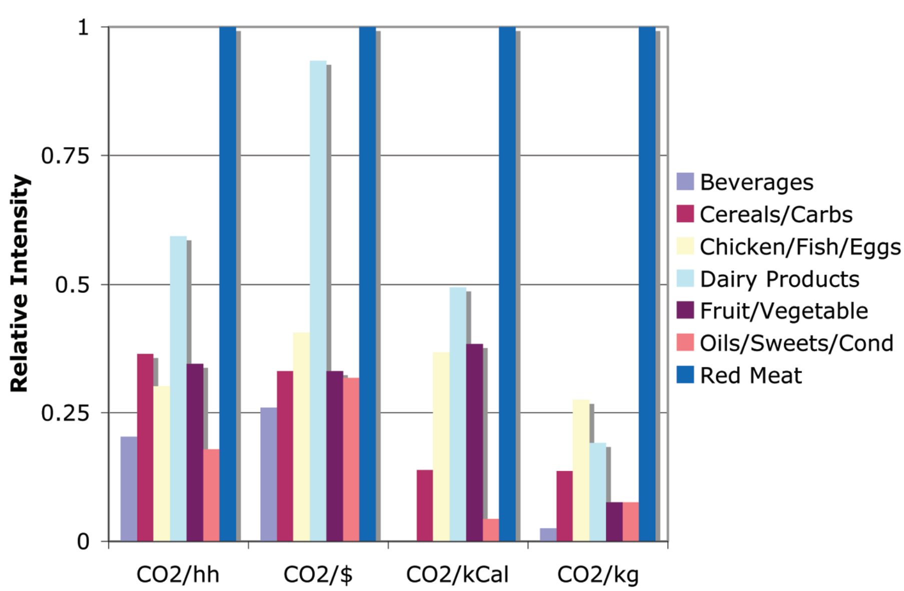

FIGURE 2. Comparison of normalization factors for total GHG of food. From left to right: no normalization (t CO_2e/hh-yr), by expenditure (g CO_2e/\$1997), by energy content (g CO_2/kCal) and by mass (kg CO_2e/kg). All values are shown relative to the value of red meat (2500 kg CO_2e/yr, 2.4 kg CO_2e/\$, 10.8 g CO_2e/kCal, 22.1 kg CO_2e/kg).

Figure 1a shows a breakdown of this total by commodity groups modeled after the USDA food groups (*29*). A 50-commodity breakdown is available in the Supporting Information but is aggregated here for illustrative purposes. Of the 12 000 t-km/yr per household, 3000 t-km were due to the "direct" tier of the food supply chain, i.e., delivery from the farm or production facility to the retail store. In general, this is the distance that advocates of the food-miles concept have identified as relevant for decision making. Thus, the total supply chain of food contains around four times the "food-miles" of just final delivery. To put these figures into perspective, when combined with the fact that the average

household consumes around 5 kg of food per day (*29*), average final delivery of food is 1640 km (1020 mi), and the total supply chain requires movement of 6760 km (4200 mi). Food groups vary in these average distances from a low of beverages (330 km delivery, 1200 km total) to a high of red meat (1800 km delivery, 20 400 km total).

By food group, the largest contributor to freight requirements is cereals/carbohydrates (14% of total), closely followed by red meat (13%). Fruits/vegetables represent another 10% of the total, with nonalcoholic beverages, fats/sweets/condiments, dairy products, nonred meat proteins (including chicken, fish, eggs, and nuts), and other miscellaneous processed food products (mostly frozen foods) all representing around 6–8% each. Final delivery (direct t-km) as a proportion of total transportation requirements varied from a low of 9% for red meat to a high of around 50% for fruits/vegetables, reflecting the more extensive supply chains of meat production (i.e., moving feed to animals) compared to human consumption of basic foods such as fruits/vegetables and grains. By transport mode, the majority of transportation in the total food supply chain is done by four modes: international water (29%), truck (28%), rail (29%), and inland water (10%). Oil and gas pipelines each represent around 3% of the total, and air and international air transport combine for less than 1% of total t-km. This differs from the final delivery portion of the supply chain, which is dominated by trucking (62%), with some international water (19%) and rail transport (16%).

When measuring in terms of GHG emissions rather than t-km, the situation changes substantially due to the significant differences in energy intensity between transport modes. GHG emissions associated with transport, again converted to a per-household basis, totaled 0.91 t CO_2e/yr, with 0.36 t CO_2e/yr associated with final delivery, i.e., "food-miles". As seen in Figure 1b, trucking is now responsible for the vast majority (71%) of transport-related GHG emissions due to its large share of t-km and relatively high GHG intensity. The remainder of emissions are associated with gas pipelines (7%), rail (6%), air transport of passengers (5%), international water (4%), inland water (3%), and international air freight (2%). The prominence of gas pipelines is mostly due to gas-fired power plants and nitrogenous fertilizer production, while air passenger transportation (moving people within the supply chains of making goods) occurs in small quantities throughout all supply chains but especially in retailing and restaurants. Fruits/vegetables now represent as large a household share as carbohydrates, 23% of total CO_2e, due to their higher percentage of trucking as a mode. For a similar reason, since trucking does the vast majority of final delivery, the importance of final delivery goes up from an average of 24% of total t-km to 39% of total GHG emissions from transport. This result lends some credence to the focus on food-miles, although it would also say that upstream transportation requirements are still more important than final delivery of food.

Regardless, the focus on food-miles and transport must be analyzed in terms of the overall climate impact of food. Results in Figure 1c show the breakdown of total life-cycle GHG emissions associated with household food, in terms of final delivery, supply chain (nondirect) freight, production, and wholesaling/retailing. Total GHG emissions are 8.1 t CO_2e/household-yr, meaning delivery accounts for only 4% of total GHG emissions, and transportation as a whole accounts for 11%. Wholesaling and retailing of food account for another 5%, with production of food accounting for the vast majority (83%) of total emissions.

Within food production, which totaled 6.8 t CO_2e/household-yr, 3.0 t CO_2e(44%) were due to CO_2 emissions, with 1.6 t (23%) due to methane, 2.1 t (32%) due to nitrous oxide, and 0.1 t (1%) due to HFCs and other industrial gases. Thus, a majority of food's climate impact is due to non-CO_2 greenhouse gases. Nitrous oxide (N_2O) emissions, mainly due to nitrogen fertilizer application, other soil management techniques, and manure management, are prevalent in all food groups but especially in animal-based groups due to the inefficient transformation of plant energy into animal-based energy. Methane (CH_4) emissions are mainly due to enteric fermentation in ruminant animals (cattle, sheep, goats) and manure management, and are thus concentrated in the red meat and dairy categories.

Different life-cycle stages have different importance among the different food groups. Delivery "food-miles" account for a low of 1% of red meat's GHG emissions to a high of 11% for fruits/vegetables, due to the higher overall emissions intensity of red meat and the lower intensity of fruits/vegetables. Total supply chain freight transportation similarly ranged from 6% of red meat and dairy's impacts to 18% of impacts of both fruits/vegetables and nonalcoholic beverages.

The results have so far focused on the total impacts of the average household in the United States, but comparing among the different types of food is more relevant for consumers wishing to lower the climate impact of their food consumption. However, comparing among food groups is a nontrivial matter. Different food groups have different prices, provide people with different nutrients, and of course are more or less pleasant to eat depending on consumers' tastes. Three possible normalizations for the impacts of different food types are used here for comparison with the total impact numbers: expenditures on food, which is related to consumer demand for food, mass of food, and energy content, which are a rough measure of food's sustenance. None are a perfect measure; expenditure is only roughly related to the amount of energy/sustenance that food provides, and calories measure only one dimension of sustenance—energy—without accounting for vitamin, mineral, and other nutritional content. Nevertheless, they provide three different ways of comparing food types and their life-cycle GHG emissions.

Figure 1d shows the total GHG emissions of food groups normalized by expenditure ($1997), and Figure 2 shows a comparison of total impacts with impacts normalized by expenditure, calories, and mass (all shown comparative to the absolute figure for red meat). Both figures show a clear trend for red meat; no matter how it is measured, on average red meat is more GHG-intensive than all other forms of food. Dairy products are an interesting second, as normalization by expenditure produces a GHG-intensity similar to that of red meat (2.2 kg CO_2/$ for dairy, 2.4 kg CO_2/$ for red meat) but normalization by calories (since dairy products are in general caloric compared to their price) produces a number around half as intensive as red meat (5.3 g CO_2/kCal compared to 10.8 g CO_2/kCal). Normalization by mass makes dairy look even better, due to the high water content (and thus mass) in the form most consumed, milk. Interestingly, on a per-expenditure basis, the impacts of all the other food groups (including the averaged restaurants group, which is low due to higher prices than eating at home) are remarkably similar in impact, though for different reasons. In both measures, fruits and vegetables compare similarly to nonred meat protein sources (chicken/fish/eggs/nuts) because although they have lower production impacts, they have higher impacts due to delivery and transportation. Carbohydrates and oils/sweets, in contrast, appear similar to other groups normalized by expenditure but appear much better normalized by calories due to naturally high energy contents per mass.

Given these differences in GHG intensities, the relative importance of "localizing" food supply vs choosing different combinations of foods can be examined. To explore this issue, we assume that the absolute maximum localization, "total localization", of the average diet would be an elimination of

TABLE 2. Shifts in Expenditure (Top) or Calories (Bottom) from Row Category to Column Category Which Result in a GHG Reduction of 0.36 tCO_2e/Household-yr, the Equivalent of a Totally "Localized" Diet ("Non-dairy Veg Diet" Represents the Average American Diet Less All Meat and Dairy)

$expenditure	chicken	grains	fruit/veg	nondairy veg diet
red meat	24%	21%	21%	21%
dairy	42%	37%	37%	36%
meat + dairy	15%	14%	14%	13%
kCal	**chicken**	**grains**	**fruit/veg**	**nondairy veg diet**
red meat	22%	17%	23%	17%
dairy	93%	33%	107%	38%
meat + dairy	18%	11%	19%	12%

all delivery miles for all foods, approximately 0.36 tCO_2/yr from Figure 1c. While this assumption is unrealistic for many reasons, it does show the upper-bound potential GHG reduction of localization. We compare this potential reduction to equivalent reductions that could be made by shifts in food choice. Table 2 shows the breakeven percentages of expenditure or calories, in shifting from red meat/dairy/both, to other foods in the columns which would reduce household GHG emissions as much as a total localization of all consumed food.

It is clear that even with the unrealistic assumption of zero food-miles, only relatively small shifts in the average household diet could achieve GHG reductions similar to that of localization. For instance, only 21−24% reduction in red meat consumption, shifted to chicken, fish, or an average vegetarian diet lacking dairy, would achieve the same reduction as total localization. Large reductions are more difficult in shifting away from only dairy products (at least on a calorie basis) but making some shifts in both red meat and dairy, on the order of 13−15% of expenditure or 11−19% of calories, would achieve the same GHG reduction as total localization.

Discussion

Uncertainties in Results. This analysis contains several difficult to quantify uncertainties. There are well-known uncertainties with input−output analysis in general and these have been documented previously (*33, 34*). In addition to these standard uncertainties, the most important of which are aggregation of unlike goods together and a time lag of data, there are several specific uncertainties in the data and methods used here. With respect to the calculation of freight transport, it is clear that the average household analyzed here is not representative of the actual placement of any single home in the United States—the average distances to market are much smaller for some households and much larger for others. Similarly, there are also deviations from the average energy intensities per t-km used here; for example, refrigerated trucking and ocean shipping of fresh foods are more energy-intensive than the average intensity of trucking or ocean shipping. However, neither of these uncertainties are likely to change the overall results of the paper substantially; even a household twice as far from its source of food would have only 8% of food-related GHG emissions associated with delivery and 15% with transport as a whole.

One potential change since 1997 which could affect the average results is the increase in imports to the U.S. (*34*), which would increase the average distance to market for some foods and increase the supply chain length for all commodities. To analyze the potential impact of this change, a simplified model based on previous work (*34*) was built assuming 2004 import data and transport distances instead of 1997 data. The resulting difference on a per-household basis was substantial in terms of t-km, increasing total t-km/household-yr from around 12 000 to around 15 000, with a corresponding increase in direct food-miles from around 3000 to 3700 t-km/household-yr. Thus, globalization from 1997 to 2004 increased the average distance moved by food by around 25%, from 1640 km (1020 mi) directly and 6760 km (4200 mi) in total to 2050 km (1250 mi) directly and 8240 km (5120 mi) in total. While this is a remarkable shift in terms of distance, because ocean shipping, which is greater than 99% of total international ocean and air shipping, is far less energy intensive than overland trucking, the total increase in the GHG emissions associated with transport is only 5%, from 0.91 t CO_2/household-yr (0.35 direct) to 0.96 t CO_2/household-yr (0.36 direct). Thus, even with the large shift in distance traveled due to globalization, the climate impacts of freight supply chains remain dominated by overland truck transport and significantly smaller than the production impacts of food.

Of course, many other uncertainties are important in the calculation of the production impacts of food. The first major uncertainty is ignoring land use impacts, which is estimated to contribute up to 35% of total GHG impact of livestock rearing (*10*). While deforestation is linked to global food markets, tracing its impacts directly to consumer demand for food is a difficult task, especially given the recent confluence of biofuel and food markets; nevertheless, it should be noted that the actual climate impacts of food production are much larger than just emissions of CO_2, CH_4, and N_2O. Additionally, while working at the aggregate and average level used in this analysis has many advantages, it does miss substantial variation in local scale impacts (N_2O emissions from soils, differing manure management and fertilizer application practices between farms, etc.; see ref (*35*) for further discussion) and in specific food types within aggregate groups (such as differences between ruminant and nonruminant red meat, grass-fed vs grain-fed meat, organic vs conventional produce, etc.). Further, several authors have noted the importance of seasonal variations and increased storage necessary for localization of produce, which are all only treated in an averaged sense here (*7, 8*). Thus, all numbers presented should be regarded as averaged and approximate, though it should be noted that most of these major uncertainties (land use, increased storage) would make the benefits of localization look even more dubious compared to dietary shift.

Relevance of Results. The production and distribution of food has long been known to be a major source of GHG and other environmental emissions, and, for many reasons, it is seen by many environmental advocates as one of the major ways concerned consumers can reduce their "carbon footprints". Proponents of localization, animal welfare, organic food, and many other interest groups have made claims on the best way for concerned consumers to reduce the impacts of their food consumption. The results of this analysis show that for the average American household, "buying local" could achieve, at maximum, around a 4−5% reduction in GHG emissions due to large sources of both CO_2 and non-CO_2 emissions in the production of food. Shifting less than 1 day per week's (i.e., 1/7 of total calories) consumption of red meat and/or dairy to other protein sources or a vegetable-based diet could have the same climate impact as buying all household food from local providers.

We estimate the average household's climate impacts related to food to be around 8.1 t CO_2e/yr, with delivery "food-miles" accounting for around 0.4 te CO_2e/yr and total freight accounting for 0.9 t CO_2e/yr. To put these figures into perspective, driving a 25 mi/gal (9.4 L/100 km) automobile 12 000 miles/yr (19 000 km/yr) produces around 4.4 t CO_2/yr. Expressed in this manner, a totally "localized" diet reduces GHG emissions per household equivalent to 1000 miles/yr (1600 km/yr) driven, while shifting just one day per week's calories from red meat and dairy to chicken/fish/eggs or a vegetable-based diet reduces GHG emissions equivalent to

760 miles/yr (1230 km/yr) or 1160 miles/yr (1860 km/yr), respectively. Shifting totally away from red meat and dairy toward chicken/fish/eggs or a vegetable-based diet reduces GHG emissions equivalent to 5340 mi/yr (8590 km/yr) or 8100 mi/yr (13 000 km/yr), respectively. Which of these options is easier or more effective for each climate-concerned household depends on a variety of factors, though given the difficulty in sourcing all food locally, shifting diet for less than one day per week may be more feasible.

It should again be noted that the analysis performed here was based on the "average" U.S. household's food expenditures. Of course, different real households will have very different dietary habits and climate profiles. Those consuming more in high-impact categories could have even more potential reduction in GHG emissions than calculated here. Of course, this is conversely true for households which already exhibit low-GHG eating habits. For these households, freight emissions may be a much higher percentage of the total impacts of food, and especially will be important for fresh produce purchased out of season.

Finally, it should be noted that this analysis only examined climate impacts, which are only one aspect related to food choice, and are only one dimension of the environmental impacts of food production. Food choice is based on a variety of factors, including taste, safety, health/nutrition concerns (both between different food types and among food types, i.e., organic vs conventional), affordability, availability, and environmental concerns. Similar to food choice in general, consumers who have taken part in the localization movement have done so for many reasons other than energy and climate; supporting local agricultural communities and food freshness are often listed as reasons to "buy local" as well. Though this analysis shows that some food types are much less GHG-intensive than others, any attempt to change consumer behavior based on only one dimension of food choice is unlikely to be effective.

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Supporting Information Available

Detailed discussion of model development and methods, detailed commodity-level results, and additional figures and tables. This material is available free of charge via the Internet at http://pubs.acs.org.

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