Institute for Agriculture and Trade Policy

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The Institute for Agriculture and Trade Policy works locally and globally at the intersection of policy and practice to ensure fair and sustainable food, farm and trade systems.

Introduction

As national governments move toward negotiating the next international agreement on climate change, and states and regions across the United States work to meet already established state greenhouse gas (GHG) emission reduction targets, what is the role of agriculture and food systems?[1] According to several recent estimates, these sectors are significant contributors to global climate change, both in the U.S. and worldwide.[2] This is largely due to agricultural land conversion and degradation, and the fact that the industrialized farming systems that dominate today, especially in the U.S. and Europe, depend on massive resource inputs to produce crops and livestock. These systems also produce carbon dioxide (CO_2) emissions from fossil fuel use and soil respiration, nitrous oxide (N_2O) emissions from fertilizers and soils, and methane from livestock, all of which contribute to global warming.

But it doesn't have to be this way. First of all, food production can be much less fossil fuel and input-intensive. And by shifting to agricultural systems that can increase carbon sequestration in soils, farming can reduce its own GHG emissions, and actually help reduce overall greenhouse gases in our atmosphere.

To meet the challenges associated with a GHG-restricted world and shifting climate, our food and agricultural systems need to be transformed. As a sector that is especially vulnerable to the effects of climate change, our agricultural systems must integrate mitigation and adaptation: not only must they adapt to more unstable weather and shifting climate patterns, but they must also result in fewer overall GHG emissions. To achieve this, our food and agricultural systems must be diverse, decentralized, resilient and synergistic.

A climate-friendly food system:

- Adapts to more dramatic temperature and water cycles;
- Employs ecological closed-loop principles where the waste from one process feeds another;
- Relies on perennials, crop rotations and cover crops to rebuild and protect the soil, store carbon and absorb water;
- Supports locally relevant practices and technologies; and
- Incorporates experience-based knowledge, adaptive management and feedback into farm management.

In order to make this transition, we need to understand the major causes of global warming emissions in today's food and agriculture systems, and ways to reduce them while still meeting our food needs. The U.S. food and agriculture system, including U.S.-based agribusiness firms, extends its reach well beyond the United States. A shift from a carbon-intensive to a climate-friendly agriculture and food system in the U.S. will not only reduce GHG emissions, but will also support such practices around the world. In this paper, we identify the actual contributions of today's food and agriculture systems in the U.S. to global warming, and offer specific principles and practices throughout the food supply chain that can be used to move toward a climate-friendly system.

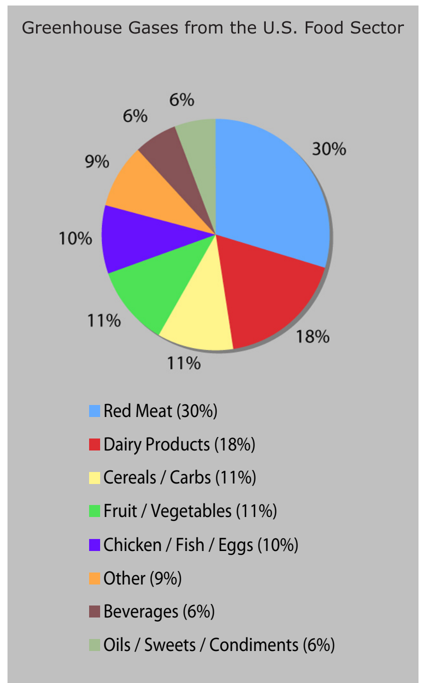
Impacts overview

An assessment of the climate impacts of food requires an examination of the full life cycle of production. The associated GHG emissions need to be assessed at each stage throughout the supply chain—from planting or (animal) raising, harvesting, processing, shipping, selling, cooking, all the way to disposal. The take-home message from a quick analysis of several recent studies is that in the food sector, ***on-farm activities are the most significant overall GHG contributor in the U.S.***, more than food transport, processing or preparation.[3] While this does not mean that other stages of the food life cycle are not important to address from a GHG emissions perspective, it does mean that the highest level of reductions likely to be identified and realized will be found on the farm.

The top contributors to climate change from the U.S. farm system:[4]

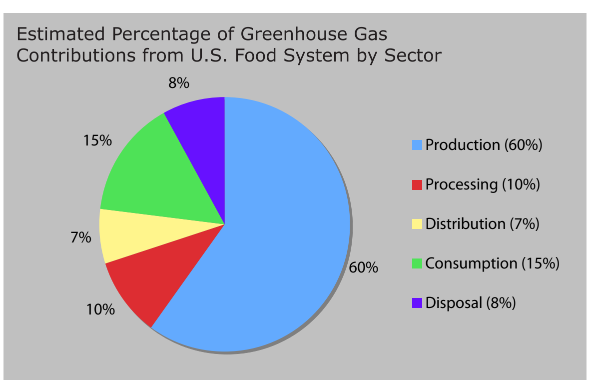
- Nitrogen oxide (N_2O) emissions caused by excessive use of synthetic fertilizers, which reach the atmosphere through soil emissions, water runoff and poor manure management.
- Methane emissions from ruminant animals, released during digestion and manure decomposition.
- CO_2 emissions from the fueling and manufacture of on-farm machinery.
- CO_2 emissions from the energy used for the manufacture and transport of fertilizers.

Among different foods, there is a large variation in what contribution is made to the typical American household's climate footprint. These differences are based on not only the makeup of our diet, but also different methods used to produce those foods. As one recent Carnegie Mellon study shows, red meat and dairy together make up almost half of a typical U.S. household's food-based GHG emissions.[5] This is because of the CO_2, N_2O and methane output from livestock, and also because the U.S. population eats a large amount of meat (per capita average consumption is more than 200 pounds per year, according to the U.S. Department of Agriculture).[6]



From Weber and Matthews, 2008.

The relative GHG contribution from different stages of the food supply chain also varies depending on the type of food and how that food is produced. For conventionally grown food, production constitutes over half of food's life cycle GHG emissions. This is primarily because of the high global warming potential of N_2O (from synthetic fertilizers) and methane (from livestock production).[7] Food processing contributes approximately 10 percent of the total GHG emissions, mostly from packaging and energy demand at the processing plant. Food's distribution from the farm gate to the retail location is a smaller piece (between 5 and 15 percent), but is growing with the increase in international air freight. The energy used for consumption, which includes both refrigeration and cooking, is typically responsible for between 5 and 30 percent of GHG emissions. Finally, food that decomposes in a landfill can release approximately 4 to 8 percent of the food supply chain's life cycle GHG emissions as methane, a byproduct of organic decomposition.



These estimates are based on a number of recent studies that have attempted to quantify the food system's contribution to climate change.[8] Each stage is discussed in more detail below.

Agricultural production

Between 50 and 70 percent of GHGs from livestock; about 50 percent of GHGs from fruits, vegetables and grains

The agricultural production stage is the highest GHG contributor for most foods and for the food sector overall in the United States. Agricultural production includes all activities that happen on or upstream from the farm or livestock operation, including the energy used for fertilizer production, the manufacture and use of farm equipment, the energy and inputs used for feed production, the enteric emissions of livestock, and the carbon uptake and release of crops. One reason that production dwarfs other stages of the food chain from a GHG perspective is because of the N_2O emissions from fertilizer and methane emissions from livestock, both of which are more potent global warming gases than CO_2. The production stage will almost always dominate livestock's climate contribution because of the large releases of methane from animal digestion (in the case of ruminants) and manure-related emissions and feed-related emissions for grain-fed cattle. However, for pastured livestock systems, there is also a significant potential carbon sequestration value from the grass production, which can reduce the "net" GHG emissions associated with animals raised in these systems.

Climate-friendly practices:

Reduce external inputs—especially synthetic and fossil-fuel based chemicals—and high GHG emissions by mimicking natural systems and using integrated practices to close waste loops:

- Make waste useful by using the outputs from one process as inputs to another. This practice is first and foremost important for animal manure, which traditionally has been the major fertilizer source and only recently has been replaced on many crop farms with synthetic fertilizer. Integrating animal husbandry with crop production on the same farm and at an appropriate scale can reduce or even eliminate the need for synthetic fertilizers. In addition, if manure is composted before land application, some of the methane emissions related to livestock can be reduced.

- Increase the productivity of land, water and nutrient resources through coupled production. As one example, many potato and dairy farmers in Maine are working together, increasing the profitability of both operations through reduced fertilizer and feed costs.[9]

- Promote the "environmental services" potential of agricultural lands for sustainable wildlife habitat, carbon sequestration, water filtration, water storage and other functions. Many rice farmers in Arkansas and California flood their fields after harvest, which creates an attractive feeding ground for migratory birds and other species. This method of rice cultivation controls weeds and pests, and also can reduce the overall methane and N_2O release from rice fields.[10]

Minimize on-farm energy requirements through efficient practices, and use renewable energy sources to provide heat, electricity or other services:

- Maximize the use of energy from the sun and animal labor (which includes the use of draft animals, but in the U.S. context is more focused on the use of livestock management systems that allow the animals to do much of the food "collection" and fertilizer "distribution" work through grazing), and minimize inputs of conventional fossil fuels. This includes the direct use of fossil fuels, as well as the indirect energy required to manufacture farm equipment. From a life cycle perspective, the efficiency of equipment and also its embedded energy, i.e., the energy used for its fabrication and transport, needs to be considered.

- Rely on solar and wind energy where possible for on-farm services such as drying crops. Whether it means leaving the crop in the field to air dry, using corn cribs that allow air circulation and natural drying, or looking to newer approaches, such as using a zero-energy method that circulates air using a hollow-blade windmill at the top of the structure, there are many ways to reduce fossil fuel energy use in crop storage.[11]

- Heat greenhouses with renewable sources, ground heat pumps, or waste heat from on-site generation (such as from an anaerobic digester).

- Reduce the net land requirements of energy production by integrating energy production and other land uses. For example, use solar panels where shade is required, or wind turbines where livestock graze. These practices would not decrease the amount of land available for crop production.

Practices specific to livestock production:

- Minimize the life cycle climate impacts of animal feed, most notably the nitrogen- and carbon-intensive growing practices for feed grain production. To avoid these feed production issues, sustainable grazing of native grasses by ruminant animals should be prioritized. Hogs can be fed with food scraps to reduce organic waste and high input feed production, and poultry can be integrated with other crop or animal production through feeding of waste grain and targeting insects that otherwise could create a pest problem.

- Co-generation or methane capture can be a significant renewable energy opportunity. Methane is a natural part of ruminants' digestive process. However, methane is also released from animal manure and decomposing organic matter, which can be captured to provide heat or electricity through small scale and community digesters. The Strauss creamery in Marin, California, runs a methane digester from cow manure and powers about 95 percent of the farm, including an electric car.[12]

- Compost animal waste with plant matter to create a nutrient-rich fertilizer. Composting of manure can reduce methane and GHG emissions, while creating a higher value fertilizer than direct manure applications.[13]

Practices specific to crop production:

- Avoid synthetic nitrogen fertilizers, which are energy-intensive to produce and release N_2O when they interact with air and water. Organic production does not use synthetic fertilizers.

- Maintain diversity in seed stocks and, where possible, in field plantings to increase adaptation abilities among plant species.

- Employ soil practices that build carbon. Rely on perennials, which build soil organic matter through their root system and absorb water more readily, which restores groundwater and reduces flooding and erosion.[14] Use crop rotations and cover crops, including nitrogen-fixing legumes, wherever possible to reduce soil emissions and to increase soil carbon.

- Extend the growing season through passive solar hoophouse structures or heat greenhouses using renewable sources, such as geothermal pumps. Inefficient fossil fuel heat can increase the climate impact of fruits and vegetables many times over.

Beyond "farm scale" considerations:

- While we generally speak of farm-related GHG emissions on a farm-by-farm basis, there is also some consideration needed on a more regional or watershed basis. Zoning that encourages a mix of farms and natural habitats could lead to not only reduced agricultural GHG emissions, but also better water quality, wildlife habitat and other public benefits.[15] For example, the Florida Everglades restoration project is an ambitious attempt to lessen agriculture's impact on the ecosystem by considering land-use decisions at the watershed scale, not only at the scale of private property ownership.

Processing

Ten percent of GHGs from food[16]

Food processing can occur on the farm for some small operations, but typically food passes through one or many separate processing stages before it reaches the consumer. Processing includes washing and bagging vegetables; canning, freezing and dehydrating foods; butchering and slaughtering livestock; and preparing processed foods. It also includes the production of packaging used for food storage. Processing does not include transport to and from the facility (which is included in distribution) or management of the wastes at processing facilities. Processing can be on the order of 10-20 percent of a food product's life cycle GHG impact, especially for prepackaged meals or other prepared foods. Most of this impact comes from the heat and electricity requirements of processing equipment.

For packaging, plastics and aluminum are the most energy-intensive packaging to produce. Paper and glass are less so, although the heavy weight of glass adds to its transport energy burden, which can be significant for long-distance hauls.[17] Aluminum is one of the most recyclable materials. Certain plastics are as well, but not all plastics can be recycled, and the process is more energy intensive than for paper or glass recycling.

Climate-friendly practices

Minimize packaging overall. Where needed, use packaging that is reusable, degradable or recyclable:

- Use refillable packaging to eliminate consumer waste and the need for primary materials production. Existing examples for food are coffee, honey and peanut butter dispensers where the customer uses a reusable container. The bulk containers can additionally be designed to optimize for transport, which can save on costs.

- Bioplastics (plastics made from bio-based material) are a promising new packaging option, as they offer the potential for lower GHG emissions in production and use than traditional fossil-fuel derived virgin plastics, and are technically recyclable and compostable. However, the infrastructure for collecting, sorting and recycling/composting these new materials ranges from very immature to non-existent, which limits both the use and realized climate benefits of bioplastics today.

Use energy-efficient practices at processing facilities:

- Upgrade to energy efficient lighting and equipment.

- Use efficient motors or size motors for optimal efficiency.

- Make use of waste heat and energy generated by on-site operations to heat or cool buildings or provide other useful services.

Minimize the energy consumption of food preservation methods over the lifetime of the product:

- There are numerous ways to preserve fruits and vegetables to make produce available out of season, but there are trade-offs, and the best method will depend on specific factors. However, the least energy-intensive options for off-season produce are always to consume locally produced food that is grown in a renewably fueled greenhouse or to preserve foods using renewable resources. Dehydrating fruits and vegetables using solar energy is the most efficient way to preserve food, but hot air drying using fossil fuel energy can require more energy than canning or freezing.

- Among non-renewable options to obtain off-season produce, the least intensive conventional method (on average) is to buy produce grown sustainably in warmer areas, provided air transport is not used.[18] The most energy-intensive approach is to eat fruits and vegetables grown in conventional greenhouses, followed by frozen foods and canned foods.[19] Frozen produce reduces the weight of what is shipped, but requires energy-intensive cold storage over the life of the product (including during transport, at the retail location and at home).

Compost or make other useful products out of wastes from processing facilities:

- Organics can be collected in municipal compost programs and returned to the farm for animal feed, compost or soil amendments.

- Animal residues remaining after slaughter can be made into useful products like tallow or biodiesel. Research is being done to test the feasibility of using animal waste for bioplastics, though this is most likely an energy-intensive process.[20]

More small scale processing facilities to reduce long transport distances between the farm and a centralized facility.

Transportation

Between five and 15 percent of GHGs from food

Transportation encompasses the entire network required to move food products through the supply chain. It generally includes transport from the farm to a centralized processor, then to a wholesaler or distributor, and finally to the retail location or food service provider (e.g., restaurants). This total transport network can average between 1,000 to 2,000 miles for meat and produce, and much higher for multi-ingredient processed foods.[21] It can also be higher for foods that might be processed in multiple locations, such as sending meat and poultry to China for processing, the "components" of which are then shipped to the U.S. and India, for example. The relative impact of transport increases significantly for heavy items with high water content (like produce or vegetables), for low-density cereals and grains, and for processed foods that have multiple steps in their distribution chain. Transport distance is also critical in the chilled distribution chain for perishable goods, which is more energy intensive than standard shipping.

However, just as important as the total travel distance are the method(s) of transport that are used. Air transport has by far the highest GHG emissions per ton-km of food, followed by trucking, then ocean freight and rail.[22] Global supply chains are energy-intensive, and they also increase the vulnerability of the food system if regions become wholly dependent on food imports. There has recently been growth in energy-intensive cold chains and air freight related to imported produce, driven by the demand for year-round produce and more exotic fruits and vegetables. It is unclear if this trend will continue as air shipping costs increase.

Although consumer transportation impacts are not included as part of the GHG impact of the food system, it is important to acknowledge the need to reduce the carbon-intensity of consumer transport for food shopping. A 10-mile food shopping trip once a week in a car that gets 25 miles per gallon is responsible for about one-half ton of CO_2 per year, while the average U.S. household's red meat impact is two-and-a-half tons per year.[23]

Climate-friendly practices

Minimize the total distance and time in transport by prioritizing local sales, sourcing and consumption:

- Many food distributors around the country are following consumer demand and buying and selling locally produced food. One example is Cherry Capital Foods in Michigan.[24]

Create regional distribution systems:

- Instead of a highly aggregated and horizontal distribution system, several regional hubs can purchase from and supply a smaller area. At the national scale, even Wal-Mart announced plans to sell $400 million worth of locally grown produce in 2008, primarily to reduce distribution and transportation costs.[25] Another leading example is Kimberly-Clark, which has restructured its U.S. supply chain around nine regional distribution centers to save on energy and fuel costs.

Choose transportation modes with the lowest possible carbon footprint:

- This could include biking or walking for short, local deliveries, low or zero emission vehicles for regional distribution, and rail or ocean freight for long-distance distribution.

Use the transportation network to close a waste loop:

- For example, a network of biodiesel trucks that fuel up using waste oil from restaurants can make use of a product that would otherwise be thrown away.

Retain and publicize key pieces of information that can help inform consumer preferences:

- Knowing where the food was grown, the size of the farm, which transport methods were used for its delivery, and so on, along with environmental "foodprint" information can help consumers make decisions in favor of climate-friendly products. For example, food labeling efforts in the UK include labels for air freighted foods and a trial run with Tesco supermarkets to label the carbon footprint of different food items. In Minnesota, a local restaurant, the Red Stag, has conducted its own carbon footprint and is working now with local farmers and organizations to identify the emissions related to the production of the local food it serves.

Food consumption and disposal

Food shopping, less than five percent of GHGs from food
Cooking, less than five to 30 percent of GHGs from food[26]
Refrigeration, 10 percent of GHGs from perishables
Landfill decomposition, five percent of GHGs from food[27]

The consumer stage of food use is not usually included in life cycle analysis estimates, which end at the point of sale and therefore do not account for the climate contribution from food preparation or disposal. But for certain products, especially vegetables and grains, cooking and refrigeration energy use can be significant.[28] In addition, a household's volume of food waste and disposal method can either send organic waste to a landfill where it produces methane as it decomposes, or turn it into compost, which emits carbon dioxide, but can offset the use of some synthetic fertilizers. Food disposal challenges are exacerbated by the large amount of food that is wasted in U.S. households, estimated at 15 percent of food purchases.[29]

Climate-friendly practices

Construct diets around low-impact food options:

- Eat less meat and dairy. When eating meat and dairy, choose pasture-raised.
- Eat fewer foods that require refrigeration or freezing.
- Purchase produce when it is in season.
- Grow food at home or in community gardens.
- Eat less processed foods and more whole foods.

Reduce the energy intensity of refrigeration and cooking methods:

- Use the most efficient cooking methods while maximizing the use of cooking heat (e.g., cooking multiple dishes at once). Solar ovens are an interesting low-energy option for some cooking.
- Use smaller refrigerators, refrigerators that use renewable electricity or cold storage/fruit cellar/ice boxes (especially during winter).
- Shop more frequently for perishable foods that require refrigeration in order to reduce the size of refrigerator that a household requires. One possibility is to increase home or work delivery options for consumers, which could also reduce individual grocery trips by consumers.

Avoid food waste and spoilage:

- Buy only what you need.
- Compost all non-consumed food waste on-site, at a neighborhood location or return the food waste to a farm. Several cities have initiated curbside compost programs, including Toronto, Ontario; Portland, Oregon; and San Francisco, California. Most of this compost is collected from residents and businesses, and then returned to regional farms.
- Restaurants, markets and other food industry facilities can donate leftover edible food to food pantries.

Conclusion

The agricultural sector contributes as much as 10 to 20 percent of the GHG emissions from industrialized countries. At the same time, our food system is highly vulnerable to the effects of climate change. If we are to meet the food needs of a growing population, it is incumbent upon us to begin the movement toward a climate-friendly food system that is resilient and adaptive to unpredictable weather change and shifting climate zones.

The greatest climate impact from most foods occurs at the agricultural production stage. Food processing and packaging have a lower impact, but remain energy-intensive and produce large amounts of waste. Transportation and consumer choices about food storage, preparation and disposal can also be significant components of food's life cycle climate impact. While the total impact will vary greatly among different food types, it is clear that a shift toward on-farm nutrient cycling practices, fresh foods, decreased packaging and shorter transport distances are areas where efforts could have a significant climate benefit.

It is essential moving forward that international, national and local policies related to GHG reduction support this shift toward a climate-friendly agriculture and food system. New international rules will be discussed in Copenhagen in December. Congress is promising to debate domestic climate legislation this year. States and cities are implementing their own carbon policies. Corporations and the private sector are looking to reduce their carbon footprint. And many in the agriculture community are already transitioning toward climate-friendly practices.

Of course, climate cannot be the only goal in reconfiguring our food and agricultural system. Fortunately, the practices listed in this paper can help not only to make our food system less of a climate problem and more of the climate solution, but can also help create healthier, more sustainable, and resilient food and agricultural systems. A shift toward practices that diversify marketable products, close waste loops, and reduce the need for external energy and fossil fuel inputs will help mitigate the climate problem, reduce energy use and pollution, and create more adaptive food and agricultural systems. A more localized food system will reduce transportation-related emissions, and increase a region's food security. So, while climate may be the driver of many of these changes, the outcomes will help lead to a more sustainable food system overall.

Notes

[1]Meetings are being held throughout 2009 to determine the next international treaty that will follow the first commitment period of the Kyoto Protocol, with the United Nations Framework Convention on Climate Change (UNFCCC) conference being held in Copenhagen, Denmark, in December (See the UNFCCC Web site at: www.unfccc.int). In the U.S., states across the country have already set aggressive local emission reduction goals (See the Pew Center on Global Climate Change: http://www.pewclimate.org/what_s_being_done/targets). For work done in Minnesota, see: http://www.mnclimatechange.us/MCCAG.cfm.

[2]Steinfeld et al. (2006) estimate that livestock activity alone accounts for as much as 18 percent of greenhouse gases worldwide, including land and forest degradation in developing countries. Bellarby et al. (2008) estimate that the global impact from agriculture is between 17 and 32 percent of anthropogenic emissions. The U.S. EPA estimates that on farm agricultural activity accounts for 7 percent of U.S. emissions, which does not include land use change, or upstream industrial or downstream transportation activity that supports agriculture (U.S. EPA 2008).

[3]From Weber and Matthews (2008), Carlsson-Kanyama (2003), Pimentel and Pimentel (2003), Saunders and Barber (2007), Morgan et al. (2007), Steinfeld et al. (2006), Pimentel et al. (2008), Garnett (2007).

[4]From Weber and Matthews (2008), Carlsson-Kanyama (2003), Pimentel and Pimentel (2003), Saunders and Barber (2007), Morgan et al. (2007), Steinfeld et al. (2006), Pimentel et al. (2008), Garnett (2007).

[5]From Weber and Matthews (2008), Carlsson-Kanyama (2003), Pimentel and Pimentel (2003), Saunders and Barber (2007), Morgan et al. (2007), Steinfeld et al. (2006), Pimentel et al. (2008), Garnett (2007).

[6]This includes both red meat and poultry consumption. For more information, including projected consumption, see: http://www.ers.usda.gov/Briefing/baseline/livestock.htm.

[7]Nitrous oxide (N_2O) has a global warming potential that is 296 times that of CO_2, and methane's CO_2 equivalent is 23.

[8]The percent of GHGs that are contributed from each stage of the food chain was adapted from Weber and Matthews (2008). However, that study did not separate the processing stage from production, and it did not include the food consumption and disposal stage. Therefore, additional information was collected to separate out the processing stage (Garnett 2007, Van Hauwermeiren et al. 2007, Dutilh and Linnemann 2004, Pimentel et al. 2008) and to add on end-of-life contribution (Carlsson-Kanyama et al. 2003, Büsser 2008, Dutilh and Linnemann 2004, Garnett 2007). These numbers are estimates and are based on a review of existing literature, not a comprehensive analysis. They should serve as a compass for future climate and food policy work, but should not be interpreted to represent a "typical" food item or the U.S. food system in aggregate.

[9]Maine Dairy and Potato Farms Joining Forces: http://www.umaine.edu/mafes/impacts/dairy.htm.

[10]Chengfang Li et al., Nitrous Oxide Emissions from Wetland Rice–Duck Cultivation Systems in Southern China, Archives of Environmental Contamination and Toxicology, 2008.

[11]See Lovins et al., *Natural Capitalism* (2000). The North Iowa Cooperative Elevator in Clear Lake also has an example of efficient drying system, which saves them about $20,000 a year in energy costs.

[12]http://www.strausfamilycreamery.com/?title=greenhouse%20gases.

[13]Information on safe manure practices is available from the Organic Trade Association http://www.ota.com/organic/foodsafety/manure.html.

[14]Researchers at the Land Institute in Salina are breeding plants to perennialize our major grain crops, starting with wheat. For more info, see: landinstitute.org.

[15]This idea is offered by Jules Pretty in "Agroecological Approaches to Agricultural Development."

[16]Pimentel (2008) estimates that processing and packaging account for 23 percent of energy use in the food system (this numbers is smaller when all greenhouse gases are included).

[17]Dutilh and Linnemann (2004).

[18]These numbers are close and highly variable depending on the specifics. Dutilh and Linnemann (2004), Carlsson-Kanyama (2003), Garnett (2007).

[19]However, one advantage of canning fruits and vegetables is that it discards the non-edible parts of food before transport, which minimizes the weight of food that is shipped the final distance to the consumer.

[20]http://www.sciencealert.com.au/news/20082705-17382.html.

[21]Extensive research on food miles has been conducted by the Leopold Center for Sustainable Agriculture's Marketing and Food Systems Research group.

[22]This is based on the GREET model.

[23]Numbers based on Weber and Matthews (2008).

[24]http://www.npr.org/templates/story/story.php?storyId=17840850.

[25]See the press release at http://walmartstores.com/FactsNews/NewsRoom/8414.aspx.

[26]The high end is estimated for crops that have low energy intensive production (wheat, potatoes) when cooking is inefficient (electric); in this case, the CO_2 from cooking can be equivalent to the CO_2 for crop production, making them each about one third of the life cycle. (Carlsson-Kanyama 2001.)

[27]This assumes that 15 percent of household purchased food is wasted, and that the average American consumes 2,200 pounds of food per year. The EPA gives an estimate that 0.72 tons of CO_2 are created in methane for every ton of disposed food, (based on given methane conversion ratios and the wet/dry ratio of food waste). Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks, p. 85 (2002). The contribution from food waste is larger if the upstream GHG emissions are attributed to the wasted food. In this case they are already counted under each upstream activity.

[28]ESU study: for coffee water boiling can be 70 percent of the energy, frozen spinach refrigeration is 50 percent of the GHG, though butter is mostly production.

[29]Timothy Jones, Using Contemporary Archaeology and Applied Anthropology to Understand Food Loss in the American Food System, Bureau of Applied Research in Anthropology, University of Arizona, 2004.

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