Food, Fuel, and Freeways:

An Iowa perspective on how far food travels, fuel usage, and greenhouse gas emissions



by

Rich Pirog, education coordinator, Leopold Center for Sustainable Agriculture
Timothy Van Pelt, student, Iowa State University Agriculture & Biosystems Engineering
Kamyar Enshayan, adjunct assistant professor, University of Northern Iowa
Ellen Cook, summer intern, Leopold Center for Sustainable Agriculture

LEOPOLD CENTER

Leopold Center for Sustainable Agriculture
209 Curtiss Hall
Iowa State University
Ames, Iowa 50011-1050
Website: http://www.leopold.iastate.edu/

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For more information contact:
Rich Pirog, education coordinator
Phone: (515) 294-1854
e-mail: rspirog@iastate.edu

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Executive Summary

Most consumers do not understand today's highly complex global food system. Much of the food production and processing occurs far away from where they live and buy groceries. External environmental and community costs related to the production, processing, storage, and transportation of the food are seldom accounted for in the food's price, nor are consumers made aware of these external costs. Examples of external environmental costs are the increased amount of fossil fuel used to transport food long distances, and the increase in greenhouse gas emissions resulting from the burning of these fuels.

Local and regional food systems, where farmers and processors sell and distribute their food to consumers within a given area, may use less fossil fuel for transportation because the distance from farm to consumer is shorter. This paper discusses transportation from farm to point of sale within local, regional, and conventional food systems. Using fresh produce and other foods as examples, we considered miles traveled, fossil fuels used, and carbon dioxide emissions, and assessed potential environmental costs.

A food mile is the distance food travels from where it is grown or raised to where it is ultimately purchased by the consumer or end-user. A Weighted Average Source Distance (WASD) can be used to calculate a single distance figure that combines information on the distances from producers to consumers and amount of food product transported. U.S. Department of Agriculture Agricultural Marketing Service produce arrival data from the Chicago, Illinois terminal market were examined for 1981, 1989, and 1998, and a WASD was calculated for arrivals by truck within the continental United States for each year. Produce arriving by truck traveled an average distance of 1,518 miles to reach Chicago in 1998, a 22 percent increase over the 1,245 miles traveled in 1981.

A WASD was calculated for a sampling of data from three Iowa local food projects where farmers sold to institutional markets such as hospitals, restaurants, and conference centers. The food traveled an average of 44.6 miles to reach its destination, compared with an estimated 1,546 miles if these food items had arrived from conventional national sources.

Would there be transportation fuel savings and reduction in carbon dioxide (CO_2) emissions if more food were produced and distributed in local and regional food systems? To answer this question, we calculated fuel use and CO_2 emissions to transport 10 percent of the estimated total Iowa per capita consumption of 28 fresh produce items for three different food systems. A number of assumptions were used regarding production origin, distance traveled, load capacity, and fuel economy to make the calculations. The goal was for each of the three systems to transport 10 percent by weight of the estimated Iowa per capita consumption of these produce items from farm to point of sale.

The *conventional sys*tem represented an integrated retail/wholesale buying system where national sources supply Iowa with produce using large semitrailer trucks. The *Iowa-based regional system* involved a scenario modeled after an existing Iowa-based

distribution infrastructure. In this scenario a cooperating network of Iowa farmers would supply produce to Iowa retailers and wholesalers using large semitrailer and midsize trucks. The *local system* represented farmers who market directly to consumers through community supported agriculture (CSA) enterprises and farmers markets, or through institutional markets such as restaurants, hospitals, and conference centers. This system used small light trucks.

The conventional system used 4 to 17 times more fuel than the Iowa-based regional and local systems, depending on the system and truck type. The same conventional system released from 5 to 17 times more CO_2 from the burning of this fuel than the Iowa-based regional and local systems.

Growing and transporting 10 percent more of the produce for Iowa consumption in an Iowa-based regional or local food system would result in an annual savings ranging from 280 to 346 thousand gallons of fuel, depending on the system and truck type. The high end of this fuel reduction would be equivalent to the average annual diesel fuel use of 108 Iowa farms. Growing and transporting 10 percent more of the produce for Iowa consumption in an Iowa-based regional or local food system would result in an annual reduction in CO_2 emissions ranging from 6.7 to 7.9 million pounds, depending on the system and truck type.

These fuel savings and CO_2 reductions may seem small when considering total fuel use and CO_2 emissions in Iowa, but our estimates represent less than 1 percent of total Iowa food and beverage consumption by weight (not including water). If a higher percentage of other foods and beverages were grown and/or processed in Iowa, the reduction in fuel use and CO_2 emissions from food transport would undoubtedly be much greater.

This paper shows that fresh produce transported to Iowa consumers under the current conventional food system travels longer distances, uses more fuel, and releases more CO_2 than the same quantity of produce transported in a local or Iowa-based regional food system. Given that fuel expenses are only a small percentage of total transportation and distribution costs, however, fuel energy costs will need to rise significantly if they are the only factor considered in determining whether local and regional systems are economically competitive with the conventional system. Economic value must be assigned to the external environmental cost of burning more fossil fuels and releasing more CO_2. The authors strongly urge that more baseline research be conducted comparing the energy efficiency and external environmental costs of production, processing, packaging, and transportation sectors of conventional, regional, and local food systems.

Introduction

A food system includes the production, processing, distribution, sales, purchasing, preparation, consumption, and waste disposal pathways of food. In Iowa and across the nation, the level of interest in local and regional food systems – where local farmers sell their products to nearby consumers – is growing. One example of a local food system is community supported agriculture, which establishes a partnership between farmers and consumers. In a typical Iowa community supported agriculture (CSA) enterprise, consumers pay a given amount to a farmer or group of farmers before the start of the growing season, sharing in some of the risk of producing the food. The food is then delivered directly to the consumer or is picked up at a designated location. Other examples of local food systems include farmers markets, roadside stands, on-farm sales, pick-your-own operations, production/processing/retail enterprises, and sales to hotels, restaurants, bed and breakfast inns, and institutions.

Most consumers do not understand the current national and global food production system, in which most of the food production and processing occurs far away from where they live and buy their groceries. Yet an increasing number of consumers have shown an interest in locally or regionally produced foods. Researchers at Oregon State University surveyed both working class and more affluent community residents in the Portland area and found that 44 percent of residents in both groups expressed moderate to strong support for buying local products.[1] Practical Farmers of Iowa recently interviewed Iowa wholesale food distributors, retail store managers, chefs, institutional food service managers, and cooperative buyers as part of a Leopold Center-supported project. All of the representatives expressed an increased interest in buying Iowa-grown meat and produce to satisfy rising consumer demand, and also agreed that there is a small but expanding market for organically or sustainably grown products.[2]

In the past 30 years there has been a significant global increase in fossil fuel use. One reason for the rise in U.S. fossil fuel use is the increased use of trucks to transport goods. In 1965, there were 787,000 combination trucks registered in the United States, and these vehicles consumed 6.658 billion gallons of fuel.[3] In 1997, there were 1,790,000 combination trucks that used 20.294 billion gallons of fuel.[4] Many of these trucks transport food throughout the United States. A recent study indicated that in California alone more than 485,000 truckloads of fresh fruit and vegetables leave the state every year and travel from 100 to 3,100 miles to reach their destinations.[5]

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[1] Stephenson, Garry and Larry Lev. *Oregon State University Extension Service*. Portland, OR, Oregon State University. September 1998.

[2] Practical Farmers of Iowa "Grocery and Hotel, Restaurant and Institution Study." April, 2000. Scanlan & Associates in cooperation with Gary Huber and Robert Karp.

[3] U.S. Department of Transportation, Federal Highway Administration, Highway Statistics 1997.

[4] ibid.

[5] Hagen, J.W., D. Minami, B. Mason, and W. Dunton. 1999. "California's Produce Trucking Industry: Characteristics and Important Issues." Center for Agricultural Business, California Agricultural Technology Institute, California State University – Fresno.

The predicted peak in world oil production, according to petrogeologists and other oil experts, will occur in 5 to 20 years.[6] [7] After that time oil increasingly will be more expensive to obtain. Yet projections are for motor gasoline and diesel fuel demand to increase 1.4 and 2.3 percent per year, respectively, through the year 2020.[8]

The burning of these fossil fuels releases carbon dioxide (CO_2) and other gases known as greenhouse gases that absorb heat and may contribute to an increase in global warming. Considering all sectors of the economy, Iowa emits 29 tons of carbon dioxide annually on a per capita basis.[9] Total U.S. greenhouse gas emissions in 1999 were 11.6 percent higher than 1990 emissions.[10] The largest source of CO_2 and overall greenhouse gas emissions in the United States was fossil fuel combustion, accounting for 80 percent of global warming potential (GWP)[11] -weighted emissions in the 1990s.[12]

Estimates suggest that a doubling of atmospheric carbon dioxide will result in an increase of 4.5° F in the planet's average annual temperature.[13] Recently the Intergovernmental Panel on Climate found stronger evidence of the human influence on climate change. According to the scientists' estimates, earth's average surface temperature could be expected to increase by 2.7° F to nearly 11° F by the end of this century if greenhouse emissions are not curtailed.[14] The Kyoto Global-Warming Accord Treaty,[15] signed by the United States in 1998, calls for industrial countries to achieve a 5.2 percent reduction of heat-trapping greenhouse gases from 1990 levels. The United States, the world's largest emitter of greenhouse gases, would have to make cuts of seven percent.[16] In late March 2001, the Bush administration opposed the Kyoto Accord on the grounds that ratification would put an unfair burden on the United States and damage the economy.[17] Efforts to

[6] Richard A. Kerr. "The Next Oil Crisis Looms Large – and Perhaps Close." August 21, 1998. *Science* 281: pp. 1128-1131.
[7] Duncan, R.C. 2001. "World energy production, population growth, and the road to Olduvai Gorge." *Population and Environment* 22(5): 503-522.
[8] Annual energy outlook forecasts of average annual growth in transportation energy demand (percent) Web site April 2001 (http://www.eia.doc.gov/oiaf/aeo/tbl24.html).
[9] Ney, R.A., J.L. Schnoor, N S.J. Foster, and D.J. Korkenbrock. 1996. "Iowa Greenhouse Gas Action Plan." Report prepared for the Iowa Department of Natural Resources by the Center for Global and Regional Environmental Research Public Policy Center, University of Iowa.
[10] U.S. Greenhouse Gas Emissions and Sinks: 1990-1999. 2001 (Draft). pp. ES-1.EPA. Web site May 2001 (http://www.epa.gov/globalwarming/publications/emissions/us2001/2001-inventory.pdf).
[11] The concept of a global warming potential (GWP) has been developed to compare the ability of each greenhouse gas to trap heat relative to another gas. Carbon dioxide was chosen as the reference gas for the GWP.
[12] U.S. Greenhouse Gas Emissions and Sinks: 1990-1999. 2001 (Draft). pp. ES-1. EPA. Web site May 2001 (http://www.epa.gov/globalwarming/publications/emissions/us2001/2001-inventory.pdf).
[13] Gale Group Web site February 2001. (http://www.gale.com/freresrc/earthday/2000/greenhs.htm).
[14] Herbert, H. Josef. "Global warming fears grow." *Des Moines Register*, October 26, 2000.
[15] The Kyoto Global Accord Treaty calls for sharp reductions in heat-trapping greenhouse gases by the United States and 37 other industrial nations.
[16] Herbert, H. Josef. "Delay Sought in Climate Talks." Lycos News. January 24, 2001. Web site March 2001 (http://news.lycos.com/head.article.asp?docid=APVO695&date=20010124)
[17] "The World Can't Wait for Another Climate Treaty." Worldwatch Institute News Release. Worldwatch Institute Web site April 2001(http://www.worldwatch.org/alerts/010328.html).

persuade the United States to endorse the Kyoto Accord at the European Union/United States summit in June 2001 ended in stalemate.[18]

Certain states, regions, and countries are said to have "comparative advantages" to producing food at the cheapest possible cost. But external environmental and social costs related to food production, processing, storage, and distribution are seldom accounted for in the price of the food.[19] It is argued that if these costs were internalized, such "comparative advantages" would be significantly reduced or eliminated entirely. Examples of environmental external costs are the increased amount of fossil fuel used to transport food and the increase in greenhouse gases emitted as the result of the burning of those fuels. One likely advantage to local and regional food systems is the reduced distance that the fresh or processed food travels from farm to point of sale. Shorter transportation distances may mean less fossil fuel is burned and fewer greenhouse gases are released into the atmosphere.

Using fresh produce and other foods as examples, this paper will discuss transportation and distribution within local, regional, and conventional food systems, determining miles traveled, fossil fuels used, and greenhouse gases released.

Objectives

1. Provide a brief overview of the changes in Iowa's food system.

2. Provide an overview of the research on energy use in the food system, with emphasis on the transportation/distribution sector.

3. Using several global, Iowa, and Midwest examples, discuss the distances that food travels (from farm to point of sale) and compare distances between local and conventional systems.

4. Using fresh produce as an example, compare miles traveled, fossil fuel used, and carbon dioxide emitted in the transport sector of several food systems.

5. Make recommendations for action (for consumers, farmers, food retailers and brokers, researchers and educators, and policy makers) to document external costs regarding fossil fuel energy use in the conventional food system, reduce transportation-related fuel use and CO_2 emissions in food systems, and examine potential benefits of local and regional systems.

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[18] "Summit admits to Kyoto failure." *The Guardian*. Guardian Unlimited. Web site June 2001 (http://www.guardianunlimited.co.uk/international/story/0,3604,507308,00.html)

[19] Orr, David. 1991. "Understanding the true cost of food: Consideration for a sustainable food system." Proceedings of the Institute for Alternative Agriculture, Eight Annual Scientific Symposium, Washington, D.C.: Institute for Alternative Agriculture.

Changes in Iowa's food system

Although less than 7 percent of Iowans make their living by farming, Iowa remains a predominantly agricultural state, with approximately 33 million acres of land in farms.[20] Table 1, developed by Michael Carolan in the Iowa State University Department of Sociology and based on the U.S. Agricultural Census records, shows the number of commodities produced for sale on at least 1 percent of all Iowa farms from 1920 to 1997. Iowa produced 34 different commodities on at least 1 percent of its farms in 1920, including food crops such as apples, potatoes, cherries, plums, grapes, raspberries, strawberries, sweet corn, and pears. In that same year, ten different commodities were produced on over 50 percent of Iowa's farms.

During the decades following World War II, agriculture became increasingly specialized, with many states focusing their agricultural production on certain crop and livestock enterprises. Using federal and state incentives, Iowa centered its agricultural production on commodities such as corn, soybeans, hogs, and cattle. Table 1 illustrates this decline in diversity; by the 1970s there were no fruits or vegetables produced on at least 1 percent of Iowa's farms. By 1997, only corn and soybeans were produced on over 50 percent of Iowa's farms.

With a decline in production diversity came a decrease in processing of certain crops. According to a 1922 report, Iowa led the world in canned sweet corn production.[21] In 1924 Iowa processed locally grown sweet corn at 58 canning factories in 36 different counties.[22] By 1998 sweet corn and other vegetables were processed at only two Iowa canning facilities.[23]

With the possible exception of livestock for meat production, most Iowa farms no longer produce food to supply Iowa consumers directly. The majority of the crops Iowa farmers produce leave the state as raw commodities, and processors add more value before purchase by the consumer or buyer. The change in Iowa's agriculture over time has brought about an increasing reliance on food from outside sources. For example, in 1870 nearly 100 percent of the fresh apples consumed in Iowa were grown in the state. By 1925, roughly 50 percent of the apples consumed were grown in Iowa.[24] In 1999, Iowa grew approximately 15 percent of the fresh apples consumed in the state.[25] It is assumed that other food items once produced on many Iowa farms have followed a similar pattern of decline.

There is a lack of baseline data on Iowa production and processing used for in-state consumption. In recent years, 10 percent has been used as an estimate of how much of the food Iowans consumed is grown in the state, but this figure is at best only an edu-

[20] Iowa Agricultural Statistics, 2000.
[21] Report of Dairy and Food Commissioner, Iowa. P. 41.
[22] Clowes, Harry. 1927. "Fruit and Vegetable Production in Iowa." M.S. Thesis, Iowa State College.
[23] "Food Product Directory of Iowa." 1998. Iowa Department of Economic Development.
[24] Clowes, Harry. 1927. "Fruit and Vegetable Production in Iowa." M.S. Thesis, Iowa State College.
[25] Pirog, Richard, and John Tyndall. 1999. "Comparing apples to apples: An Iowa perspective on apples and local food systems." Leopold Center for Sustainable Agriculture, Ames, Iowa.

cated guess. A 1985 report estimated that more than 90 percent of Iowa's produce demand is provided for by sources outside of the state.[26] The report indicated that Iowa farmers grew a small fraction of the fresh produce bought during the summer months by Iowa produce wholesalers and distributors for sale within the state.[27] This purchasing trend holds true in 2001.[28]

Energy use in the food system

A thorough examination of energy use in the food system is beyond the scope of this paper. An excellent 1996 summary of research and analysis of energy use in the food system, written by John Hendrickson, covers many important studies and is recommended as further background for the reader.[29] The gasoline shortages and a perceived energy crisis in the 1970s prompted a number of studies on energy use in the food system. Hendrickson's research points to a critical need to replicate studies performed in the 1970s.

New studies on energy use in all sectors of the food system are needed for a number of reasons. The nation is experiencing serious energy shortages once again, with rising prices and energy blackouts in California and other states. Increased efforts to conserve fossil fuels are being explored at state and federal levels. With increased interest in local and regional food systems, it is important to document whether these systems are more energy efficient than conventional systems, and whether an increased use of such systems will contribute to a reduction in fossil fuel use and greenhouse gas emissions.

Table 2, taken from John Hendrickson's research, averages the findings from nine studies that document energy use in various sectors of the food system.[30] The table shows that the food system accounts for almost 16 percent of total U.S. energy consumption, similar to David Pimentel's 1989 estimate of 17 percent. Table 2 also shows that transportation accounted for 11 percent of the energy use within the food system, considerably less than agricultural production (17.5 percent) and processing (28.1 percent).

Energy use by sectors also varies tremendously by the type of food considered. For example, for a one-kilogram loaf of bread more than 70 percent of the energy is used in the production and processing sectors.[31] For a one pound can of corn, those same two sectors use only 27 percent of the energy, with packaging accounting for over one-fourth

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[26] Valley, Camille. "Market Conditions for Fresh Fruits and Vegetables in Iowa." April 1985. Des Moines, Iowa: Iowa Department of Agriculture.
[27] ibid.
[28] Comments made by a food service manager with an Iowa produce distribution company, February 2001.
[29] Hendrickson, John. 1996. "Energy use in the U.S. Food System: A Summary of existing research and analysis." Sustainable Farming-REAP-Canada. Ste. Anne-de'Bellevue, Quebec. Vol 7, No. 4. Fall 1997.
[30] ibid.
[31] Pimentel, David and Marcia Pimentel. 1996. *Food, Energy, and Society*. Niwot, CO: Colorado University Press.

of the total energy used.[32] The energy used to transport a one pound can of corn home and to prepare it exceeds the energy needed to produce the corn.[33]

Life Cycle Assessment

Life Cycle Assessment (LCA) is a method for performing an integral analysis of the environmental impacts of products in a "cradle to grave" fashion.[34] [35] Energy consumption within the life cycle of a product is typically calculated while performing an LCA. The LCA method was originally developed for use with industrial products, but recent research has investigated the extent to which the LCA method is suitable for use in agricultural systems.[36] One such study estimated the total life cycle energy consumption of apples and pears to be 23 megajoules per kilogram (MJ/kg).[37] (For reference purposes, one MJ will light a 100-watt light bulb for 2.8 hours.[38]) In another study, the energy needed for a fast food-type hamburger was estimated to be between 24 and 65 MJ/kg.[39] Ground beef required the most energy of all food products needed for the hamburger (other products included were bun, lettuce, cheese, pickles, and onions).

Several studies have compared energy consumption for crops grown locally versus those imported. One study found that sourcing fresh peas locally required nearly three times less energy compared to imported peas.[40] A Swedish study compared the energy consumption of Swedish and imported carrots and found that energy consumption for the imported carrots was double that of the domestic produce.[41]

A recent University of Michigan study used an LCA approach to develop and present a broad set of sustainability indicators of the U.S. food system.[42] The assessed indicators showed that the U.S. food system is not economically, socially, or environmentally

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[32] Brown, Susan J. and J. Claire Batty. 1976. "Energy Allocation in the Food System: A Microscale View." *Transactions of the American Society of Agricultural Engineers* 19(4):758-761.
[33] ibid.
[34] The International Organisation for Standardisation (ISO). 1997. Environmental Management – Life Cycle Assessment: Principles and Framework. International Standard ISO 14040.
[35] "Application of LCA to Agricultural Products." 1996. Centre of Environmental Science Leiden University (CML), Centre of Agriculture and Environment (CLM), Agricultural-economic Institute (LEI-DLO). CML report 130. Translated by Nigel Harle.
[36] ibid.
[37] Coley, D.A., E. Goodliffe, and J. Macdiarmid. 1998. The embodied energy of food: the role of diet. *Energy Policy* 26(6):455-459.
[38] Bickerstaffe, J. and B. Tucker. 1993. Industry Council for Packaging and the environment guide to the Boustead study on resource use and liquid food packaging 1986-1990. Industry Council on Packaging and the Environment. London, 22 p.
[39] Annika Carlsson-Kanyama. 2000. "Energy Use in the Food Sector: A data survey." Dept. of Systems Ecology, Stockholm University, Sweden. AFR-report 291.
[40] Kooijman, J.M. 1993. "Environmental assessment of packaging: Sense and sensibility." *Environmental Management* 17(5):575-586.
[41] Carlsson, A. 1997. "Greenhouse gas emissions in the life-cycle of carrots and tomatoes." IMES/EESS Report No. 24, Department of Environment and Energy Systems Studies, Lund University, Sweden.
[42] Heller, Martin. C., and Gregory A. Keoleian. 2000 *Life Cycle-based Sustainability Indicators for Assessment of the U.S. Food System*. University of Michigan, Center for Sustainable Systems. Report No. CSS00-04.

sustainable. The study concluded that the most effective way to develop a more sustainable food system is to change attitudes and behaviors about food consumption.

Energy costs for marketing and transportation of food products

The 1999 energy bill for marketing food in the United States totaled $21.6 billion, accounting for 3.5 percent of retail food expenditures.[43] It is estimated that 6 to 12 percent of the consumer dollar spent on food consumed in the home represents transportation costs.[44] From 1985 through 1991, the average transportation charge for Florida tomatoes shipped to the upper Midwest was 6.3 percent of the retail cost.[45] Oil prices affect the trucking industry, which uses diesel fuel. Declining diesel oil prices through the 1990s tended to restrain food transportation cost increases.[46]

Food miles – the distance food travels from farm to consumer

A food mile is the distance food travels from where it is grown or raised to where it is ultimately purchased by the consumer or other end-user. One 1969 estimate of miles traveled by food in the United States cited an average distance of 1,346 miles.[47] Calculations made by John Hendrickson using a 1980 study examining transportation and fuel requirements estimated that fresh produce in the United States traveled an estimated 1,500 miles.[48] Fresh produce arriving in Austin, Texas, was estimated to travel an average of 1,129 miles.[49] An analysis of the USDA Agricultural Marketing Service's 1997 arrival data from the Jessup, Maryland, terminal market found that the average pound of produce distributed at the facility traveled more than 1,685 miles.[50] This same study showed the average distance for fruits to be transported was 2,146 miles, while the average for vegetables was 1,596 miles.[51]

In developed, industrial nations, food appears to be traveling farther to reach the consumer. Agricultural imports into the United States increased 26 percent by weight from 1995 to 1999.[52] One metric ton of food transported by road in the United Kingdom traveled an average distance of 77 miles in 1998 compared with 51 miles in 1978.[53] A Swedish study of food miles used the ingredients from a Swedish breakfast (apple, bread, butter, cheese, coffee, cream, orange juice, and sugar) to sum the distances that each food traveled from the producers to consumer. The mileage estimated for the meal

[43] "Food Review" 2000. 23(3):28. USDA Economic Research Service.

[44] Rhodes, V. James. 1993. *The Agricultural Marketing System*, 4th Edition. Scottsdale, Arizona: Gorsuch, Scarisbrick, Publishers.

[45] Fresh Vegetable Prices and Spreads. USDA-ERS. Web site March 2001. (http://www.ers.usda.gov/data/sdp/view.asp?f=specialty/88009/)

[46] "Food Review" 2000. 23(3):30. USDA Economic Research Service.

[47] U.S. Department of Defense. 1969. *U.S. Agriculture: Potential Vulnerabilities*. Stanford Research Institute, Menlo Park, CA.

[48] Hendrickson, John. 1996. "Energy use in the U.S. Food System: A Summary of existing research and analysis." Sustainable Farming-REAP-Canada. Ste. Anne-de'Bellevue, Quebec. Vol 7, No 4. Fall 1997.

[49] ibid.

[50] Hora, Matthew, and Jody Tick. 2001. "From Farm to Table: Making the Connection in the Mid-Atlantic Food System." Capital Area Food Bank of Washington D.C. report.

[51] ibid.

[52] "Foreign Agricultural Trade of the United States" (FATUS). 2000. Economic Research Service, USDA.

[53] DETR. 1999. "Transport of Goods by Road, 1998" HMSO, London.

was equivalent to the circumference of the earth.[54]

Calculating food miles for table grapes using a weighted average source distance (WASD)

Prior to the late 1960s, most Americans ate table grapes when the local and California markets could supply them – roughly from June through December. Since then, Americans have nearly tripled their table grape consumption from 2.52 pounds per person (per capita utilization) in the 1972/73-market year to 8.21 pounds per person during the 1999/2000-market year.[55] A major reason for this increase in consumption is the increase in the amount of imported grapes from Chile and other Southern Hemisphere countries during winter and early spring when California grapes are not available. The amount of imported grapes during this period (as a percentage of total consumed) rose from 4 to 45 percent, while exports of California grapes remained fairly steady.[56] The significant increase in imported grapes implies an increase in the average distance that table grapes travel to reach the U.S. consumer.

Methods

One way to estimate food miles is to use a weighted average source distance (WASD).[57] The WASD from production source to consumption endpoint is a single distance figure that combines information on distances from producers to consumers and the amount of food product transported. To provide perspective on the increase in food miles traveled, we have calculated the WASD for table grapes consumed in Iowa in three different years.

The formula for the WASD is:

$$WASD = \frac{\Sigma\,(m(k) \times d(k))}{\Sigma\, m(k)}$$

where:

k = different locations of the production origin,

m = amount consumed from each location of consumption origin, and

d = distances from the locations of production origin to the point of consumption.

[54] Gunther, F. 1993. "Phosphorus flux and societal structure." *A Holistic Approach to Water Quality Management: Finding Life-styles and Measures for Minimizing Harmful Fluxes from Land to Water*, Stockhom Water Symposium 10-14 August 1992, Stockholm, Sweden, Pub. No. 2. Stockholm Water Co., pp. 267-298.

[55] Specialty Crops Branch, ERS-USDA. 2000.

[56] Market and Trade Economics Division, ERS-USDA. 2000. (Reporting years represent a May to April cycle. Population figure is from January of the latter year in each case.)

[57] Carlsson-Kanyama, Annika. 1997. "Weighted average source points and distances for consumption origin-tools for environmental impact analysis." *Ecological Economics* 23(1997) 15-23.

For these calculations, we made a number of assumptions:

- Iowa's average per capita table grape consumption is equivalent to the U.S. average, and the consumption reference point is Des Moines.
- Distances are estimated by using latitude/longitude coordinates from an Internet site (http//:indo.com/distance/) to determine a direct distance that is "as the crow flies" between the two points rather than actual transport route. We chose to go with this distance estimation because transportation routes vary for table grapes imported into Iowa from Chile and South Africa.
- We have used a 1 percent floor for these calculations; only states or countries providing 1 percent or more of the total poundage of table grapes were included.
- In 1972/73 accurate import data for that year were not readily available on which countries provided fresh grapes to the United States, but it is very likely that the majority of imported grapes came from Chile. Almost all of the remaining 96 percent of the table grapes was grown in California.

Results

WASD calculations for three production years for table grapes can be found in Table 3. The 1972/73 WASD was calculated at 1,590 miles. In 1988/89, the WASD had increased to 2,848 miles, an 89 percent gain over the 1972/73 figure. Most of this increase in distance can be explained by the significant increase in exports of Chilean table grapes to the United States and the corresponding increase in annual consumption. In 1998/99, the WASD was relatively unchanged at 2,839 miles, primarily because of the increase in Mexican table grape imports relative to the total amount of table grapes consumed. (Mexican table grapes had a slightly shorter transport distance from production [Mexico] to consumption point [Des Moines] than the California-grown grapes.)

Other uses for the WASD

The WASD for table grapes has been calculated in other countries. In Sweden, a WASD for table grapes was calculated using a consumption point in Stockholm, Sweden. The WASD increased by almost 100 percent from 1965 to 1992.[58] This change reflects an increase in imports of table grapes grown in Chile, Australia, and the United States.

The WASD can be estimated from production and shipping records for various fresh fruits, vegetables, meats, and other foods. It is much more complicated to calculate the WASD for multi-ingredient processed products.

Using the WASD to calculate food miles for produce arriving at the Chicago, Illinois terminal market

One late 1970s estimate indicated that in the United States approximately 60 percent of food and related products were transported from the farm by truck and the remaining 40 percent by rail.[59] In the past 25 years, with an improved road infrastructure in the

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[58] Carlsson-Kanyama, Annika. 1997. "Weighted average source points and distances for consumption origin-tools for environmental impact analysis." *Ecological Economics* 23(1997) 15-23.

[59] Pimentel, David, and Marcia Pimentel. 1979. *Food, Energy, and Society*. New York: John Wiley and Sons.

United States and other developed nations, the amount of food transported by truck has increased dramatically. According to a 1996 USDA study, nearly 93 percent of fresh produce transported between cities in the United States was moved by truck.[60]

The USDA's Agricultural Marketing Service (AMS) tracks shipments and exports of fresh fruits and vegetables by commodities, modes of transportation, origins, and months in the calendar year. The AMS also tracked produce arrivals at various terminal markets throughout the United States until budget limitations forced the elimination of this data collection in 1998.[61] Terminal markets for produce have declined in importance in the United States; currently there are only 22 major terminal markets that handle an estimated 30 percent of the volume of the nation's produce.[62] The decline in terminal market share is a reflection of the increased purchasing power of integrated wholesale-retail buying entities.[63]

Although terminal market share has declined, the arrival data collected through 1998 provide a realistic picture of where produce comes from during the calendar year. To provide an upper Midwest perspective on how far food travels, we examined the arrival data at the Chicago, Illinois terminal market collected by the AMS for the years 1981, 1989, and 1998. Chicago was chosen over other terminal markets because of its proximity to Iowa and the assumption that it approximated the purchasing source percentages of integrated wholesale-retail produce buyers in Iowa.

Methods

The Chicago terminal market arrival data document the total amount of produce that arrived at the market from states, countries, and territories. We used the data to calculate two WASDs; one for produce arriving from locations in the continental United States by truck, and one for total arrivals by truck that originated from outside of the continental United States. We calculated arrivals by truck and rail as a percentage of total arrivals for produce grown within and outside the continental United States. We also calculated arrivals by truck from California and Florida as a percentage of total arrivals. The following assumptions were made in the calculations:

- For the truck WASD calculations, distances from the production origin within the continental United States and Canada to the terminal market were estimated by using a city located in the center of each state as the production origin. (In Canada we took the average distance from the center of two major produce areas to Chicago.) Then we calculated a one-way road distance to Chicago using the Internet site Mapquest (mapquest.com).

[60] U.S. Department of Agriculture Agricultural Marketing Service. 1996.
[61] Douglas Edwards, USDA Agricultural Marketing Service, February 2001. Personal communication.
[62] Cook, Roberta. 2001. "The Dynamic U.S. Fresh Produce Industry: An Industry in Transition." *Postharvest Technology of Horticultural Crops*, Third Edition. Adel A. Kader. University of California Division of Agriculture and Natural Resources. (In press.)
[63] ibid.

- Distances from Puerto Rico, Hawaii, and other countries to Chicago were calculated using the Internet site (http//:indo.com/distance/) which uses latitude and longitude to determine a direct distance that is "as the crow flies" between the two points rather than actual transport route. This was done because it is difficult to find the data to determine the shipping routes taken to each customs port in the United States, and transportation routes from the port to Chicago.

Results

Table 4 shows the WASD for produce arriving by truck at the Chicago terminal market from within the continental United States and by truck from outside of the continental United States for 1981, 1989, and 1998. The table also shows the percentage of produce arrivals each year that is carried by rail and truck from the continental United States, by truck from California and Florida, and from other countries, states, and territories outside of the continental United States.

In 1981, produce traveled an average of 1,245 miles by truck from locations within the continental United States to reach the Chicago terminal market. The average distance for produce arriving by truck in the continental United States increased to 1,424 miles in 1989, and to 1,518 miles in 1998. The 1998 estimate is a 22 percent increase in distance over the 1981 figure.

In 1981 about 50 percent of produce from all locations arrived by truck and 50 percent by rail. (When considering only the continental United States, 46 percent arrived by truck and 54 percent by rail.) In 1998 nearly 87 percent of the produce arriving at the Chicago terminal market from all locations came by truck. (Almost 84 percent arrived by truck when considering locations within the continental United States.) The rise in average distance traveled by truck is likely due, in part, to the increase in total amount of produce arriving by truck, and subsequent decrease in arrivals by rail. Rail accounted for only 13 percent of the total produce arriving at the Chicago market in 1998 (16 percent when considering produce originating within the continental United States).

California and Florida supplied a combined 38.4 percent of produce from all sources in 1981 and 45.7 percent in 1998. No other state, with the exception of Wisconsin in 1981, supplied more than 6 percent of the produce per year from all sources for the three years anlayzed.

In 1981 about 12.5 percent of the produce arriving by truck at the Chicago terminal market from all locations was grown outside of the continental United States. That percentage rose to 16.4 percent in 1989, and increased to 21.5 percent in 1998. The WASD for arrivals by truck of produce originating from outside of the continental United States was 2,160 miles in 1981, increased to 2,633 miles in 1989, but decreased to 2,242 miles in 1998. The decrease in 1998 was likely due to a significant increase in produce arriving from Mexico (13.5 percent of total in 1998 compared with 4.5 percent in 1989 and 3.6 percent in 1981).

Comparison of food miles – Iowa local food system examples

Table 5 compares the distances traveled for locally and regionally grown foods used in three meals compared with the distances traveled if those foods came from conventional sources outside of the state. The average total distance for the three locally sourced meals was 1,198 miles. The average total distance for the meals using the same meal ingredients obtained from conventional sources was 12,558 miles, more than 10 times the distance. WASDs were not used in this example.

A number of local food system projects, including several supported by the Leopold Center, have been initiated in Iowa over the past several years. These projects have reported success in increasing sales of locally grown and processed produce, meats, and beverages to hotels, restaurants, and institutions such as hospitals, universities, schools, restaurants, workplace cafeterias, and conference centers. To contrast the distance food travels in a locally-based versus a conventional system, we compared WASDs for several Iowa institutional projects with WASDs for a conventional system sourcing the same products within the continental United States.

Methods

A sample of food distribution data from three Leopold Center-funded local food projects in Black Hawk, Johnson, and Story counties was used. Data were available on total pounds of product delivered, delivery location, and address of the grower. Food items included meat and produce. One-way distance from the farm to institution was estimated using the Internet site Mapquest (mapquest.com). Using this information, we estimated a WASD for each project, and a combined WASD across all three projects. We then calculated a WASD for each project site and a combined WASD across all project sites for the same food items, assuming they were produced in a state that currently supplies Iowa with a significant amount of that food.

Results

Table 6 shows the WASD comparisons. The local food traveled an average distance of 44.6 miles across all food projects, while that same food would likely travel an average of 1,546 miles if it came from conventional sources. When considering produce only, the local food traveled an average distance of 37.9 miles, while the produce would likely travel an average of 1,638 miles if it came from conventional sources.

Food miles, fossil fuel use, and greenhouse gas emissions

As mentioned in Table 2 and in the section "Energy use in the food system" the food system was estimated to account for 16 percent of total U.S. energy consumption. Agricultural activities were responsible for 7.7 percent of total U.S. greenhouse gas emissions in 1997.[64] Energy use and gaseous emissions from the transport of food vary by mode of transportation. Table 7 shows the estimated values for energy consumption and for carbon dioxide and other gaseous emissions for four transportation modes.

[64] Environmental Protection Agency. 1999. "Inventory of Greenhouse Gas Emissions and Sinks: 1990-1997." EPA 236-R-99-003. U.S. Environmental Protection Agency, Washington, D.C. Web site April 2001 (http://www.epa.gov/globalwarming/publications/emissions/us1999/index.html).

Clearly, air transportation is the least energy efficient method and produces more emissions in transporting food or other goods, followed by road (truck), rail, and water.

Reductions in transport-related carbon dioxide emissions when food items are sourced locally rather than conventionally have been documented in several research studies. A recent British study showed that purchase of local apples resulted in an almost 3,000 percent reduction in energy use and 87 percent lower carbon dioxide emissions than apples imported from New Zealand.[65] The mode of transportation, however, must be taken into account before assuming that energy use and CO_2 emissions will be lower for food that is transported for shorter rather than longer distances. Table 7 shows that a given amount of food transported by water could travel seven times farther than the same amount of food transported by road (truck) and still not use more energy or release more greenhouse gases.

Comparing fuel use and CO_2 emissions for three food distribution systems

What type of transportation fuel savings would be realized if Iowa grew more of its own food? How much of a reduction in CO_2 emissions would result from the fuel savings? To help answer these questions, we have estimated fuel use and CO_2 emissions for transporting from the farm (production origin) to the point of sale 10 percent of 28 different fresh produce items that Iowans consume annually, using three different food systems.

Methods

For the purposes of this comparison, we define these three food systems as follows:

Conventional system: This is an integrated retail/wholesale buying system in which national sources supply Iowa with a significant percentage of its produce through retail supermarkets, restaurants, and other institutional markets served by brokers and distributors. Iowa now receives a good deal of produce from other countries, but to simplify calculations we chose to focus on national sources. This system uses large semitrailer trucks for transport.

Iowa-based regional system: Although there are a few Iowa farms that supply significant volumes of produce to retail supermarkets and institutions, most Iowa horticultural producers are not part of a coordinated, farmer-owned, cooperative infrastructure to grow and market fruits and vegetables. An existing network of brokers and distributors uses a regional infrastructure to deliver produce to Iowa supermarkets, restaurants and institutions, but they do not currently use a significant amount of Iowa-grown produce. We will hypothesize an Iowa-based regional system modeled after this existing system that could supply retail, wholesale, and institutional markets through some type of cooperative network of small and midsize farms. This hypothetical system would use large semitrailer trucks and midsize trucks for transport.

[65] Jones, J.A. 1999. “The environmental impacts of distributing consumer goods: a case study on desert apples.” Ph.D. Thesis. Centre for Environmental Strategy, University of Surrey, Guildford, Surrey, UK.

Local system: This represents farmers who market and sell directly to consumers or food buyers. To simplify our calculations we divided this group into two markets – selling through CSAs and farmers markets, and selling to restaurants/institutions. This system uses many different types of light-duty trucks, cars, and vans for transport. We selected light-duty gasoline trucks as the vehicle type to transport produce in this system.

Our intent was to determine whether there would be transportation fuel savings and CO_2 emission reductions if 10 percent more of the fresh produce consumed by Iowans was grown in local or regional systems. For these calculations, we made a number of assumptions.

To estimate food consumption:

- National per capita consumption data[66] (three-year average for 1997-99) were used to estimate Iowa consumption totals for all 28 selected produce items.

To select production sources for the conventional system:

- We selected a state that we were confident grew at least 10 percent of the total of Iowa's annual consumption for each of the 28 produce items. These states have a track record of supplying a significant amount of the demand to the upper Midwest during Iowa's growing season. Arrival data for 1998 from Chicago's terminal market were used as a reference. The produce/state pairings made to estimate distances can be found in Table 8.

To estimate one-way mileage in the three systems:

- For the conventional system one-way mileage from the center of the state to Des Moines, Iowa, were used to estimate the distance from farm to point of sale. Des Moines was chosen as the destination point because it is close to the center of Iowa, is at the intersection of the state's two major interstate highways, and is a major distribution point for produce. Distances were estimated by using the Internet site MapQuest (mapquest.com).
- For the Iowa-based regional system a distance of 82 miles was estimated as a one-way average travel distance from farm to point of sale. This number represented the average distance from 15 locations uniformly spread across Iowa to the two closest major Iowa market or distribution areas (Des Moines, Chariton, Cedar Rapids, Boone, Sioux City, Davenport, and Omaha, Nebraska). Choosing the two closest major market areas for each of the 15 locations provided 30 data points (15x2) for the estimation. Distances were estimated by using the Internet site MapQuest (mapquest.com).
- For the local food transport system serving institutional markets an average one-way distance of 38 miles would be used. This estimate can be found in Table 5, where we calculated the average one-way distance that local produce traveled across three institutional local food system projects.

[66] " Food Consumption, Prices and Expenditures, 1970-1999." Economic Research Service. USDA. Statistical Bulletin No. 965.

- For the local food transport system servicing CSA and farmers markets an average one-way distance of 21.2 miles from farm to point of sale would be used. This figure represents the average one-way distance from the farm to Ames for all Ames downtown farmers' market vendors and regular producers serving the Magic Beanstalk CSA. Produce distribution data (by weight) was not readily available for this local system, so a WASD could not be calculated.
- Backhauls were not included in any of the calculations because the trucks often do not return directly to their original destinations. For example, produce trucks from California traveling to the upper Midwest may unload produce in Iowa, pick up another load of goods in Iowa or another state, and then return to California.

To select transport vehicles, load capacities, and fuel economies for the three systems:

- Calculations were made for produce in the conventional and Iowa-based regional systems using heavy-duty semitrailer truck rigs that carry 40,000 pounds.[67] [68] Five percent of the load would be container weight, for a total produce weight per truck of 38,000 pounds. These heavy-duty trucks would use a gallon of diesel fuel for every 6.1 miles they travel.[69]
- Calculations in the Iowa-based regional system were made also for a midsize truck capable of hauling 14,500 pounds of produce, of which 5 percent would be container weight.[70] These midsize diesel trucks would use a gallon of diesel fuel for every 8.5 miles they travel.[71] Both semitrailer and midsize trucks are currently used to transport produce for wholesale and retail markets in Iowa.
- For the local food system we selected a light gasoline-fueled truck that could transport a maximum load of 1,635 pounds,[72] 5 percent of which is container weight. For our estimations the light trucks will use a gallon of regular gasoline for every 17.2 miles they travel.[73]

Other assumptions:

- Fuel use calculations and CO_2 emissions are based on transporting produce from farm to point of sale. Fuel used and emissions generated in production, in transport to an on-farm cooling facility, in transport for indirect routes needed for processing or storage, or by consumers to transport the produce from point of sale to home are not considered. Indirect fuel use and CO_2 emissions resulting from manufacturing

[67] Dwight Minami, Center for Agricultural Business, California State University–Fresno. February 2001. Personal communication.

[68] Hagen, J.W., D. Minami, B. Mason, and W. Dunton. 1999. "California's Produce Trucking Industry: Characteristics and Important Issues." Center for Agricultural Business, California Agricultural Technology Institute, California State University–Fresno.

[69] Bureau of Transportation Statistics, National Transportation Statistics. 1999. "Combination Truck Fuel Consumption and Travel" Table 4-14 Web site March 2001(www.bts.gov/ntda/nts/NTS99/data/Chapter4/4-14.html).

[70] Transport load and fuel efficiency represent an average for midsize trucks taken from two Iowa-based produce brokering and distribution companies.

[71] ibid.

[72] Average standard payload of six different light pick-up trucks from Chevrolet, Ford, and Dodge, 2000 models.

[73] Bureau of Transportation Statistics. National Transportation Statistics. Table 4-12 Other 2-Axle 4-Tire Vehicle Fuel Consumption (light trucks) 1999. Web site March 2001 (www.bts.gov/ntda/nts/NTS99/data/Chapter4/4-12.html).

the trucks or building the roads are not considered.

- Each of the three food systems could supply 10 percent of the estimated per capita consumption of the 28 selected produce items.

Results

Table 9 compares the fuel used, CO_2 released, and total distance traveled (from farm to point of sale) if 10 percent of the produce consumed in Iowa were distributed by conventional, Iowa-based regional, and local systems. The conventional food system's semitrailers had nearly 17 times higher fuel use and CO_2 emissions compared with the semitrailers in the Iowa-based regional system, and 8.5 times higher fuel use and CO_2 emissions than the midsize trucks in the Iowa-based regional system. The conventional food system's semitrailers traveled nearly 17 times farther than the semtrailers in the Iowa-based regional system, and six times farther than the midsize trucks in the regional system.

The conventional food system's semitrailers used more than four times the fuel when compared with the local food system's light trucks used for institutional markets, and emitted almost five times the CO_2, but only traveled 1.5 times as far as the light trucks. The light trucks had to make more trips to deliver 10 percent of the per capita consumption target. The conventional food system's semitrailers used nearly 7.5 times the fuel, emitted more than 8.5 times the $CO_{2,}$ and traveled nearly three times as far as the local food system's light trucks used for CSA and farmers markets.

Growing and transporting 10 percent more of the produce for Iowa consumption in an Iowa-based regional or local food system would result in savings ranging from 280 to 346 thousand gallons of fuel, depending on the system and truck type. The high end of this fuel saving (found in the regional system) would be equivalent to the average annual diesel fuel use of 108 Iowa farms.[74] The fuel cost savings (based on June 2001 fuel prices), depending on system and truck type, would range from \$440,377 to \$546,393.

Growing 10 percent more of the produce for Iowa consumption in an Iowa-based regional or local transport system would result in a reduction in CO_2 emissions of 6.7 to 7.9 million pounds, depending on the system and truck type.

Discussion

The calculated reductions in fossil fuels and CO_2 emissions are based on 10 percent of the estimated Iowa consumption of 28 fresh fruits and vegetables grown in the state. These reductions are quite small when considering potential savings of the recommended options to increase fuel efficiency and reduce greenhouse gas emissions made

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[74] Duffy, Michael. 1989. "Energy Use on Iowa Farms: A survey of energy use and cropping operations." Special Report SR-91-01. Leopold Center for Sustainable Agriculture. Ames Iowa.

in Iowa's 1996 Greenhouse Gas Action Plan.[75] Ten percent of these 28 produce items, however, represents less than 1 percent of total food and beverage per capita consumption by weight (not including water) in Iowa.[76] If a higher percentage of meats, processed foods, and beverages were grown and/or processed in Iowa, the reductions in fuel usage and resulting CO_2 emissions from transport would be significantly higher.

Our intent was to estimate some of the hidden environmental costs connected to the current conventional food system's reliance on semitrailers traveling great distances to bring food to Iowa. Using limited data and a set of assumptions, this study has estimated the transportation fuel usage and CO_2 emissions for three food systems. A more comprehensive study might be undertaken to include backhauls and account for produce arriving from other countries as well as the United States. One could document specific vehicle load weights for each type of produce (for example, a load of peppers will weigh less than a load of cucumbers), and track fuel efficiencies for specific truck types across different food distribution systems. A significant obstacle in undertaking such a comprehensive study is the lack of available data from public sources.

Application of results: using food miles to estimate fuel use and CO_2 emission reductions without local data

We have shown examples where food transported in local and Iowa-based regional systems travels fewer miles, uses less fuel, and emits less CO_2 than a conventional system. Are there simpler ways of estimating fuel consumption and CO_2 reductions used in food transport that might come from an increased reliance on local and regional food systems, particularly when local data are not available? One alternate approach is to develop a food system scenario where increased reliance on local and regional food systems leads to a reduction in the average distance food is transported (from production to point of sale).

We turn back to the produce arrival data from the Chicago terminal market to develop an example. Our analysis of produce arrival data at the Chicago terminal market showed that the upper Midwest relies on both national and international sources to supply most of its produce. If the upper Midwest relied more upon a multi-state regional system to provide its produce, the average distance that produce would travel from farm to point of sale would decrease.

Methods

Our intent was to estimate how much fuel would be saved and CO_2 not released if a multi-state regional food system could reduce the average produce transport distance by a certain target mileage. To estimate the possible reductions in fuel usage and CO_2

[75] Ney, R.A., J.L. Schnoor, N.S.J. Foster, and D.J. Korkenbrock. 1996. "Iowa Greenhouse Gas Action Plan." Report prepared for the Iowa Department of Natural Resources by the Center for Global and Regional Environmental Research Public Policy Center, University of Iowa.

[76] Estimate based on USDA-ERS 1996 per capita consumption data by major food categories for the United States. Beverage consumption in gallons was converted into pounds, and it was assumed that the 28 fruits and vegetables used in this study represented 75 percent of all fresh fruits and vegetables consumed. It was also assumed that the national per capita consumption data could be used to estimate Iowa consumption.

emissions, we hypothesized a multi-state regional system and compared it to the conventional system. To make the calculations, we made several assumptions.

To define our target area:

- We defined the upper Midwest as a six-state region including Iowa, Minnesota, Wisconsin, Indiana, Illinois, and Michigan, with Chicago as market hub.

To estimate food consumption:

- National per capita consumption data[77] (three-year average for 1997-99) was used to calculate per capita consumption for each of these six states for the same 28 fruits and vegetables identified in Table 8.
- Arrival data from the 1998 Chicago terminal market indicated that 84 percent of the produce arriving from within the continental United States came by truck, and the remaining 16 percent came by rail. We reduced total consumption by 16 percent so produce traveling by rail would not be included in our estimations.

To select transport vehicle type, load capacity, and fuel economy for the hypothesized system:

- The system would use a semitrailer truck that can transport 40,000 pounds (five percent of the load would be container weight, for a total produce weight per truck of 38,000 pounds) and get 6.1 miles per gallon of diesel fuel.[78] [79]
- Backhauls were not considered.

To estimate a target reduction distance:

- We subtracted the 1981 WASD from the 1998 WASD for arrival by trucks in the continental United States (shown in Table 4) and found a difference of 273 miles. We used that difference as our target reduction distance.

Results

If a regional production and distribution system used for fresh produce for this six-state region reduced by 273 miles the average one-way distance that produce traveled by truck, this reduction would translate into savings of 8.8 million gallons of diesel fuel per year. The amount of CO_2 emissions would decrease by 194.8 million pounds.

Conclusions

The infrastructure and decision-making in the current food system are based on profitability, and often do not take into account external environmental or community costs. This paper has documented several cases and scenarios where food produced within

[77] "Food Consumption, Prices and Expenditures, 1970-1999." Economic Research Service. USDA.

[78] Hagen, J.W., D. Minami, B. Mason, and W. Dunton. 1999. "California's Produce Trucking Industry: Characteristics and Important Issues". Center for Agricultural Business, California Agricultural Technology Institute, California State University – Fresno.

[79] Bureau of Transportation Statistics, National Transportation Statistics. "Combination Truck Fuel Consumption and Travel" 1999. Table 4-14. Web site March 2001 (http://www.bts.gov/ntda/nts/NTS99/data/Chapter4/4-14.html).

local or regional food systems travels fewer miles (from farm to point of sale) than the food produced within a conventional system. The shorter transportation distances for these local and state-based regional food systems led to reduced transportation fuel use and CO_2 emissions compared to the conventional system. We hope that this study will encourage others involved in local food system efforts to compare their transportation fuel use and resulting CO_2 emissions with the conventional system.

The energy crisis in California has resulted in higher prices for cooling and storing California-grown produce and other foods, resulting in higher selected food prices for distributors, retailers, and consumers.[80] High fuel costs have led to protests by independent truckers, who claim the increases threaten their livelihoods.[81] Rising fuel and electricity costs may make food distributors, brokers, and retailers more receptive to using local and regional food systems.

Given that fuel expenses are only a small percentage of total transportation and distribution costs, however, fuel costs will need to rise significantly if they are the only factor considered in determining whether local and regional systems are economically competitive with the conventional system. According to research conducted at Iowa State University in 1985, rising fuel costs did not provide a competitive advantage to producing 13 different horticultural crops in Iowa rather than shipping them in from other states.[82] This research, however, did not assign economic value to the environmental benefit of reducing fossil fuel use and greenhouse gas emissions. It also did not take into account the community benefit to increasing markets for Iowa producers. Based on our consumption estimates for the 28 fruits and vegetables discussed earlier in this paper, if an additional 10 percent of these produce items were grown and sold in Iowa, it would result in $54.3 million dollars in sales for Iowa farmers (based on wholesale prices). These dollars would multiply several times in Iowa communities rather than communities in other states or countries.

Application of findings to consumers

"Cause marketing" is marketing that connects a business' product to a particular cause or set of values, in the hope that those consumers with similar values will be more likely to purchase the product.[83] A 1997 marketing report indicated that price and quality being equal, 76 percent of consumers would switch to a brand of product they considered to be supporting a good cause.[84] Some consumers may buy a food product because it is locally grown, while others may be interested in whether it is organic, protects soil and water resources, or provides good wages and working conditions for the farm workers. Others may be looking for several of these attributes. Collaborative cause

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[80] "California Power Crisis Sends Shock Waves Nationwide," January 2001. CNN. Web site March 2001 (http://www.cnn.com/SPECIALS/2001/power.crisis/backgrounder.html)

[81] "Truckers converge on Washington to seek fuel price relief," March 2000. CNN. Web site March 2001 (http://cnn.ch/2000/US/03/16/gas.prices.01/).

[82] Weimar, Mark R. 1985. "The economic production potential for fresh summer fruits and vegetables in Iowa's commercial wholesale market with emphasis on small farms." Ph.D Thesis, Iowa State University.

[83] *Collaborative Cause Marketing Handbook for the Specialty Food Industry.* January 2000. Appalachian Center for Economic Networks.

[84] Cone, Carol L. and Mark A. Feldman. 1997. *Cause-Related Marketing Trends Report*. Boston, MA. Cone Communications.

marketing,[85] which correlates different value sets with food product attributes, may answer their needs.

We believe there is a segment of the population who support environmental causes and are concerned about CO_2 emissions and fossil fuel use. It is uncertain whether these consumers see a move to a more local or regional food system as relevant to their own cause. This paper helps to make the connection between food choices, fossil fuel use, and greenhouse gas emissions. The information may be useful for producers, processors, and retailers wanting to build relationships with consumers concerned about these environmental issues.

Locally grown food as the "load less traveled": importance of considering the entire food system

Although food transported in local and regional food systems may travel fewer miles and use less fossil fuel to reach the consumer, one cannot assume that these systems are more energy efficient compared to the conventional food system. The importance of Life Cycle Assessment (LCA) cannot be overlooked when considering transport-related fuel use and carbon dioxide emissions within the context of the entire food system. Carbon dioxide equivalents per kilogram of tomato were compared over a 20-year period for tomatoes grown in Denmark, the Netherlands, Sweden (with Sweden being the end consumption point), and other countries.[86] Spanish tomatoes were shown to have lower CO_2 equivalents than those produced in Denmark, the Netherlands, and Sweden, even though the transportation distances to Sweden were shorter than for the Spanish tomatoes. The reason is that the Spanish tomatoes were raised in open ground while the Swedish, Dutch, and Danish tomatoes were raised in heated greenhouses, which required more fossil fuel energy in crop production. Transportation energy savings for the systems with shorter transport distances were overshadowed by higher energy needs in crop production. The results of this Swedish study underscore the importance of examining fuel use and CO_2 emissions across all sectors of the food system.

Recommendations for action

These actions are suggested to better document the external costs of the current food system, reduce fuel use and CO_2 emissions from food transport, and to examine potential benefits of more local and regional food systems:

For Iowa consumers:

- Buy local or regionally grown food whenever possible. Several resources produced by the Iowa Department of Agriculture and Land Stewardship, Practical Farmers of Iowa, and ISU Extension give Iowans information on how and where to sell or

[85] *Collaborative Cause Marketing Handbook for the Specialty Food Industry*. January 2000. Appalachian Center for Economic Networks.

[86] Carlsson-Kanyama, Annika. 1998. "Food Consumption Patterns and their Influence on Climate Change." *Ambio* 27(7):528-34.

purchase food through farmers markets, community supported agriculture enterprises, direct sales, on-farm stores, and institutional markets.[87] [88]

- Grow your own fruits and vegetables, and look for opportunities to participate in community gardens.
- Plan effectively to minimize the number of shopping trips you make to purchase food. Whenever possible, coordinate your trip to the grocery store with your trip to the farmers market.
- Encourage grocery store managers and farmers market managers to work together so that farmers markets can be held in or close to the parking lots of grocery stores.
- Consult with nutritionists to encourage replacement of foods with low nutrient value with more nutrient dense fresh foods that can be easily grown in Iowa. For example, cabbage has more nutrients and can be stored for longer time periods than lettuce.

For Iowa farmers, retailers, and food brokers:

- Pursue opportunities to market produce and meats locally and regionally. These opportunities include direct marketing efforts and cooperative supply networks. Groups such as Practical Farmers of Iowa and the Iowa Network for Community Agriculture can provide information and contacts.
- Diversify production and processing to meet the growing demand for local food products.
- Research opportunities to add value to foods grown on Iowa farms.
- Work with researchers on season-extending technologies for fruits, vegetables, grains, and legumes, keeping in mind external environmental and community costs.
- Work to locate farmers markets near grocery stores and supermarkets. This would reduce consumer fuel usage and may increase business for both groups.

For food system researchers and educators:

- Conduct baseline research that compares conventional, regional, and local food systems regarding fossil fuel energy used in all sectors of the food system (production, processing, storage, transportation, distribution).
- Compare energy efficiencies and greenhouse gas emissions between truck and rail transport systems.
- Conduct baseline research to show whether increased use of local and regional food systems in the United States would decrease the ecological foot print.[89] (The ecological footprint measures human impact on nature.)
- Begin pioneering research in Iowa on the use of Life Cycle Assessments [90] [91] for specific fresh and processed food items.

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[87] "2001 Farmers' Market Directory" 2001. " Iowa Family Farm Meats Directory" 2000. Iowa Department of Agriculture and Land Stewardship Web site June 2001 (http://www.state.ia.us/agriculture).

[88] Iowa CSA Farms. Iowa State University. ISU Extension Publication. PM 1693, Revised July 2000.

[89] Redefining Progress Web site April 2001 (http://www.rprogress.org/progsum/nip/ef/ef_projsum.html).

[90] "Application of LCA to Agricultural Products." 1996. Centre of Environmental Science Leiden University (CML), Centre of Agriculture and Environment (CLM), Agricultural-economic Institute (LEI-DLO). CML report 130. Translated by Nigel Harle.

[91] Schenk, Rita C. 2001. *Life Cycle Assessment for Mere Mortals: A Primer on Environmental Life Cycle Assessment*. Institute for Environmental Research and Education, Vashon, WA.

- Develop or create simple stories that can be understood by consumers to explain the true price tag for each food item. Hidden external environmental and community costs need to be documented and presented to consumer groups. A set of educational materials entitled "Price Tags, Cost Tags,"[92] developed by the University of Wisconsin's Center for Integrated Agricultural Systems, could serve as a model.
- Develop economic models that assign value to the external environmental costs of our current food system and compare the same environmental costs with regional or local food systems.
- Continue on-farm research on extending Iowa's fruit, vegetable, legume, and grain production season, keeping in mind external environmental and social costs.
- Conduct on-farm research on renewable alternative fuels for food production, processing, and transport within local and regional food systems.

For state and federal policymakers:

- Require that national and state and local food policy councils address energy efficiency of the food system in their work.
- Modify or eliminate state and federal rules that limit commerce of local and regional food systems.
- Formulate policy that provides incentives and regulations to develop new food labels that inform consumers on the relative level of external environmental and community costs.

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[92] "Price Tags, Cost Tags" 2000. Center for Integrated Agricultural Systems, University of Wisconsin. (Materials developed for poultry, tomatoes, coffee, and other food products.)

Table 1. Number of commodities produced for sale on at least 1 percent of all Iowa farms for selected years from 1920 to 1997

1920	(%)	1935	(%)	1945	(%)	1954	(%)	1964	(%)	1978	(%)	1987	(%)	1997	(%)
Horses	**(95)**	**Cattle**	**(94)**	**Cattle**	**(92)**	**Corn**	**(91)**	**Corn**	**(87)**	**Corn**	**(90)**	**Corn**	**(79)**	**Corn**	**(68)**
Cattle	**(95)**	**Horse**	**(93)**	**Chicken**	**(91)**	**Cattle**	**(89)**	**Cattle**	**(81)**	**Soybeans**	**(68)**	**Soybeans**	**(65)**	**Soybeans**	**(62)**
Chicken	**(95)**	**Chicken**	**(93)**	**Corn**	**(91)**	**Oats**	**(83)**	**Hogs**	**(69)**	**Cattle**	**(60)**	Cattle	(47)	Hay	(42)
Corn	**(94)**	**Corn**	**(90)**	**Horses**	**(84)**	**Chicken**	**(82)**	**Hay**	**(62)**	**Hay**	**(56)**	Hay	(46)	Cattle	(42)
Hogs	**(89)**	**Hogs**	**(83)**	**Hogs**	**(81)**	**Hogs**	**(79)**	**Soybeans**	**(57)**	**Hogs**	**(50)**	Hogs	(35)	Hogs	(19)
Apples	**(84)**	**Hay**	**(82)**	**Hay**	**(80)**	**Hay**	**(72)**	**Oats**	**(57)**	Oats	(34)	Oats	(25)	Oats	(12)
Hay	**(82)**	**Potatoes**	**(64)**	**Oats**	**(74)**	Horses	(42)	Chicken	(48)	Horses	(13)	Horses	(10)	Horses	(11)
Oats	**(81)**	**Apples**	**(56)**	Apples	(41)	Soybeans	(37)	Horses	(26)	Chicken	(09)	Sheep	(08)	Sheep	(04)
Potatoes	**(62)**	**Oats**	**(52)**	Soybeans	(40)	Potatoes	(18)	Sheep	(17)	Sheep	(08)	Chicken	(05)	Chicken	(02)
Cherries	**(57)**	Cherries	(24)	Grapes	(23)	Sheep	(16)	Potatoes	(06)	Wheat	(01)	Ducks	(01)	Goats	(01)
Wheat	(36)	Grapes	(28)	Potatoes	(23)	Ducks	(05)	Wheat	(03)	Goats	(01)	Goats	(01)		
Plums	(29)	Plums	(28)	Cherries	(20)	Apples	(05)	Sorghum	(02)	Ducks	(01)	Wheat	(01)		
Grapes	(28)	Sheep	(21)	Peaches	(16)	Cherries	(04)	Red clover	(02)						
Ducks	(18)	Peaches	(16)	Sheep	(16)	Peaches	(04)	Apples	(02)						
Geese	(18)	Pears	(16)	Plums	(15)	Goats	(04)	Ducks	(02)						
Strawberry	(17)	Mules	(13)	Pears	(13)	Grapes	(03)	Goats	(02)						
Pears	(17)	Ducks	(12)	Rd clover	(10)	Pears	(03)	Geese	(01)						
Mules	(14)	Wheat	(12)	Mules	(06)	Plums	(03)								
Sheep	(14)	Geese	(11)	Strwberry	(06)	Wheat	(03)								
Timothy	(10)	Sorghum	(09)	Ducks	(06)	Red clover	(03)								
Peaches	(09)	Barley	(09)	Wheat	(04)	Geese	(03)								
Bees	(09)	Red clover	(09)	Timothy	(04)	Popcorn	(02)								
Barley	(09)	Strawberry	(08)	Geese	(03)	Timothy	(02)								
Raspberry	(07)	Soybeans	(08)	Rye	(02)	Swt potato	(02)								
Turkeys	(07)	Raspberry	(06)	Popcorn	(02)	Swt corn	(01)								
Wt.melon	(06)	Bees	(05)	Swt corn	(02)	Turkeys	(01)								
Syrup Sorg	(06)	Timothy	(05)	Raspberry	(02)										
Gooseberry	(03)	Turkeys	(04)	Bees	(02)										
Sweet corn	(02)	Rye	(02)	Sorghum	(01)										
Apricots	(02)	Popcorn	(02)												
Tomatoes	(02)	Sweet corn	(02)												
Cabbage	(01)	Swt clover	(01)												
Popcorn	(01)	Goats	(01)												
Currants	(01)														
n= 34		n=33		n=29		n=26		n=17		n=12		n=12		n=10	

Prepared by Michael Carolan, Sociology Department, Iowa State University. Data is from U.S. Census of Agriculture.

Table 2. Energy use in the U.S. food system *

Sector	Average (percent)
Production	17.5
Processing	28.1
Transportation	11
Restaurants	15.8
Home preparation	25
Food system**	**15.6**

* (Excerpted from Table 2, "Energy Use in the Food System: A Summary of Existing Research and Analysis." Center for Integrated Agricultural Systems, University of Wisconsin-Madison.)

** percentage of total U.S. energy consumption used in the food system

Table 3. Weighted Average Source Distance (WASD) for table grapes with Des Moines, Iowa as consumption point

Year	WASD (miles)
1972/73	1,590
1988/89	2,848
1998/99	2,839

Table 4. Truck WASD estimations, and truck, rail, and foreign* arrivals as percent of total arrivals

Year	1981	1989	1998
Truck WASD – continental United States	1,245 miles	1,424 miles	1,518 miles
Truck WASD – foreign arrivals*	2,160 miles	2,633 miles	2,242 miles
Arrivals by truck overall – Percent of total	49.6%	68.6%	86.9%
Arrivals by rail overall – Percent of total	50.4%	31.4%	13.1%
Arrivals by truck – Percent of total - continental U.S. only	46.4%	64.7%	84.0%
Arrivals by rail – Percent of total continental U.S. only	53.6%	35.3%	16.0%
Arrivals by truck – California			
Percent of total	25.4%	31.2%	33.3%
Arrivals by truck – Florida			
Percent of total	13.1%	12.5%	12.4%
Foreign arrivals* – Percent of total	12.5%	16.4%	21.5%

* Includes all arriving produce that is not from the continental United States (including Puerto Rico and Hawaii) except a category entitled "imports," which according to USDA-AMS is likely bananas. We did not use this category because it is difficult to know from which country the produce originated.

Table 5. Distances traveled for three locally grown meals compared to distance if same food items were supplied through conventional channels

Dinner - October 17, 1998

Food Item	Source	Distance Traveled	Distance as if through conventional channels (miles)
Chuck roast	Dan Specht (Clayton County)	75 miles	675 (CO)
Potatoes	farmers market	10-15 miles	1,300 (ID)
Carrots	our garden	40 feet	1,700 (CA)
Green beans	our garden	40 feet	1,700 (CA)
	Total Miles:	90 miles	5,375 miles

Lunch - October 18, 1998
*Roast beef hash made from left over dinner plus other items:

Food Item	Source	Distance Traveled	Distance as if through conventional channels (miles)
Onions	farmers mkt.	10-15 miles	1,700 (CA)
Green bean salad	our garden	40 feet	1,700 (CA)
Purple cabbage	farmers mkt.	10-15 miles	1,700 (CA)
Tomatoes	our garden	40 feet	1,700 (CA)
Yellow peppers	farmers mkt.	10-15 miles	1,700 (CA)
Olive bread	farmers mkt.	10-15 miles	1,700 (CA)
	Total Miles:	60 miles	10,200 miles

Table 5. (continued)

Dinner - October 18, 1998

Food Item	Source	Distance Traveled	Distance as if through conventional channels (miles) (CA)
Rice	Buying club	1,700 (CA)	1,700
Stir Fry:			
Mushrooms	Hy-Vee (grocery store)	1,700 (CA)	1,700
Oniona	farmers mkt.	10-15 miles	1,700
Green pepper	farmers mkt.	10-15 miles	1,700
Red pepper	farmers mkt.	10-15 miles	1,700
Vegetables on Side:			
Brussel sprouts	our garden	40 feet	1,700
Salad:			
Lettuce	our garden	40 feet	1,700
Yellow tomato	our garden	40 feet	1,700
Red tomato	our garden	40 feet	1,700
Basil	our garden	40 feet	1,700
Oregano	our garden	40 feet	1,700
Radish	our garden	40 feet	1,700
Carrots	our garden	40 feet	1,700
	Total Miles:	3,445 miles	22,100 miles
	Three meal average	**1,198 miles**	**12,558 miles**

Adapted from: Where Our Meals Come From
Kamyar Enshayan and Laura Jackson
Cedar Falls, Iowa

CA - California
CO - Colorado
ID - Idaho

Table 6. Comparison of WASD for food transported to institutions for three Iowa local food system projects with WASD for same food items sourced from conventional system

Project	Local WASD meat and produce (Miles)	Conventional WASD meat and produce (Miles)	Local WASD produce only (Miles)	Conventional WASD produce only (Miles)
Ames - Scheman Conference Center – PFI*	67.3	1,001	38.4	1,233
Iowa City – Johnson Co. Local Food Project	20.8	1,685	20.8	1,685
UNI Local Food Project	43.6	1,719	43.6	1,720
Overall	**44.6**	**1,546**	**37.9**	**1,638**

Notes:
Food items include apples, broccoli, onions, potatoes, strawberries, tomatoes, green beans, raspberries, salad mix, beef, and chicken. Only Scheman Conference Center included meat; the other two locations were produce only. The town closest to the farm location was used for local estimates. Source locations for the conventional system were towns or cities close to the center of a state known as a significant producer of the food item. For example, California was chosen for strawberries and Idaho for potatoes.

* PFI refers to Practical Farmers of Iowa

Table 7. Energy use and emissions for different modes of freight transport

	Rail	**Water**	**Road**	**Air**
Primary energy consumption KJ/ Tonne-km	677	423	2,890	15,839
Specific total emissions g/Tonne-km				
Carbon dioxide	41.0	30.0	207	1,260
Hydrocarbons	0.06	0.04	0.3	2.0
VOC*	0.08	0.1	1.1	3.0
Nitrogen oxide	0.2	0.4	3.6	5.5
Carbon monoxide	0.05	0.12	2.4	1.4

From: Atmosphere Emissions from the Use of Transport in the United Kingdom Volume 2. 1989. The Effect of Alternative Policies. ERR and WWF cited in Whitlegg, J. 1993. Transport for a Sustainable Future: the case for Europe. Bellhaven Press, London.

* Volatile organic compounds

Table 8. Origin of production states used to estimate distances

Produce item	State
Apples	Washington
Asparagus	California
Bell peppers	California
Blackberries	California
Blueberries	Michigan
Broccoli	California
Brussel sprouts	California
Cabbage	Georgia
Carrots	California
Cauliflower	California
Cucumbers	Georgia
Eggplant	Georgia
Grapes	California
Garlic	California
Mushrooms	Pennsylvania
Onions	California
Pears	Washington
Plums	California
Potatoes	Idaho
Radishes	Florida
Raspberries	California
Leaf lettuce	California
Snap beans	Georgia
Spinach	California
Strawberries	California
Sweet Potatoes	Louisiana
Tomatoes	California
Melons	Missouri

Notes:
We elected not to include fresh sweet corn in the calculations because we believe that Iowa sweet corn captures a significant portion of total Iowa fresh sweet corn sales during the summer months.

Per capita consumption of fresh sweet potatoes was estimated to be two-thirds of sweet potatoes for all uses (fresh, frozen, and canned). (Personal communication with Gary Lucier, ERS/USDA, March 2001.)

Table 9. Estimated fuel consumption, CO_2 emissions, and distance traveled for conventional, Iowa-based regional, and Iowa-based local food systems for produce*

Food system and type of truck	Fuel Consumption (gal/year)	$ value of fuel (current 2001 prices*)	CO_2 emissions (lbs. / year)	Distance traveled (miles)
Conventional semitrailer	368,102	$581,601	8,392,727	2,245,423
Iowa regional semitrailer	22,005	$35,208	501,714	134,230
Iowa regional midsize truck	43,564	$69,702	993,243	370,289
Iowa local -CSA farmers market small truck (gas)	49,359	$78,974	967,436	848,981
Iowa local institutional small truck (gas)	88,265	$141,224	1,729,994	1,518,155

***** Diesel fuel prices – U.S. average ($1.58) used for conventional system and Iowa average ($1.60) used for Iowa-based regional system. Iowa regular unleaded gasoline average ($1.60) used for local systems. Web site June 2001 (http://www.aaa.com/scripts/WebObjects.dll/AAAOnline?association=aaa&club=049)

Notes:
According to the U.S. Environmental Protection Agency, the most important of the greenhouse gases released through fuel burning and other human activities are CO_2, methane, nitrous oxide, hydroflurocarbons, perfluorocarbons, and sulfur hexaflouride. ("Global Warming and Our Changing Climate – FAQ". 2000. Environmental Protection Agency Office of Air and Radiation, April 2000. EPA 430-F-00-011.)

Of these, CO_2 is by far the largest component of emission gases released by diesel fuel trucks, comprising over 99 percent of the emissions by weight. (*Greenhouse Gas Inventory Reference Manual*, Intergovernmental Panel on Climate Change, 1996.)

We estimated the amount of CO_2 released from the burning of diesel fuel and gasoline for these trucks, and we used a conversion factor of 22.8 pounds of CO_2 released from the burning of each gallon of diesel fuel. (Personal communication with Cheryl Bynum and Deb Adler, EPA National Vehicle and Fuel Emissions Laboratory, April 2001.) Calculation—7.12 lb./gal (density of diesel) x 0.874 (percent carbon in diesel) x 44/12 (converting C to CO_2).

We used a conversion factor of 19.6 pounds of CO_2 released from the burning of each gallon of gasoline. (Personal communication with Cheryl Bynum and Deb Adler, EPA National Vehicle and Fuel Emissions Laboratory, April 2001.) Calculation—6.2 lb/gal (density of gasoline) x 0.865 (percent carbon in gasoline) x 44/12 (converting C to CO_2).