Energy use in the transport of food: Comparing local and conventional food systems in Berkeley, CA

Courtney Glettner

Abstract Increased global trade and the industrialization of agriculture has resulted in the globalization of the food supply. Although modern food production methods and the creation of a global food system have increased supply and decreased prices of food in many parts of the world, recently a wide range of people, from scientists to consumers, have begun to re-evaluate this new system. Concerns over food contamination and a lack of traceability, global warming, and suffering rural economies have sparked interest in the local food movement. Stated benefits of local food systems span social, economic, and environmental disciplines, and include a reduction in energy use for transportation of food. The relationship between reduction in transportation distance and reduction in energy usage has been questioned, especially when considering the loading capacity used in conventional distribution. This study researched energy usage in the transportation of produce in local and conventional food systems in Berkeley, CA through the collection of transportation data on various produce items through direct interviews. The energy used in transportation from place of production to place of purchase (per kilogram of food) was calculated for 10 different food items bought at farmers markets and conventional supermarkets. Although no statistically significant difference was found between the two food systems, important factors that resulted in higher energy use per kilogram of food were identified, including vehicle load and distance.

Introduction

Increased global trade and industrialization of agriculture has resulted in the globalization of the food supply. Previously diverse, local food systems are being amalgamated into a single global "foodshed," where the same foods are offered on every continent (Mamen *et al*. 2004). From 1965 to 1998 the amount of goods being traded across countries tripled (Norberg- Hodge *et al*. 2002). As a result of highly vertically integrated corporations with large distribution centers, the average food item in the US travels between 1500 and 2500 miles from production to consumption (Iles 2005). These "food miles," or "the distance that agricultural produce, food, food ingredients travel on the journey from farms to the consumer," result in the use of large amounts of fossil fuels and the emissions of carbon dioxide and other pollutants (Iles 2005). It is estimated that of all the energy used to produce food, only one fifth is used on the farm, and the rest in transportation and processing (Pollan 2006).

Throughout the last century, food systems world-wide have undergone numerous changes as a result of the Green Revolution and globalization. The Green Revolution, which spanned from the 1940s into the 1960s, introduced new technologies, including insecticides, herbicides, nitrogen fertilizers and mechanized machinery. These allowed crop yields to increase, increasing the food supply and thus decreasing prices. Alongside these innovative technologies, came the industrialization of agriculture. Trends in industrialized agriculture include shifts towards larger farms, high input/high output farming, highly mechanized equipment, and the planting of monoculture crop fields (Mamen *et al.* 2004). As a result of high fossil fuel inputs, including the production and application of fertilizers and pesticides, agriculture plays a major role in the global emissions of carbon dioxide, methane, and nitrous oxides, all known greenhouse gases (Robertson *et al*. 2000). Modern agriculture has shifted away from small diverse farms towards large farms only growing one crop. In 2000**,** three crops (corn, wheat, and soybeans) made up 217 million acres of the total 255 million acres planted in the United States (USDA 2000). These changes in farming have impacted the world environmentally, economically, and socially, while drastically changing the way that people experience the food that they eat.

In the past decade, however, there has been a movement to evaluate this new global food system and its effects on the environment, health, social welfare, and rural economies. Concerns over food contamination and a lack of traceability, global warming, and suffering rural economies have sparked interest in the local food movement. The local food movement, which is being embraced throughout the world, is an attempt for people to re-establish a relationship with their food, where it comes from, and who grows it (Kloppenburg 1996). Although, the term "local food system" can mean many things to many people, in general, the goals are the same: to reduce food miles and decrease the number of hands food passes through before it is sold to the consumer. Schemes to distribute food through local food systems include farmers' markets, community supported agriculture, relationships between institutions and farmers, and direct marketing to food retailers (Feagan 2007). The benefits of local food systems extend into environmental, social, and economic fields, including sustaining rural economies, reducing food miles, supporting small scale farmers, and bringing communities together through food (Lyson and Green 1999).

A specific area of research gaining attention is the overall environmental benefits of local food systems. Jones (1999) found that in a means/end analysis (MEA) of the transportation of dessert apples in the United Kingdom that there was a reduction in transport energy consumed when the product was sourced closer to the point of consumption. Directly linked with the consumption of energy is the emission carbon dioxide. A study estimating the change in energy use and carbon dioxide emitted if people in Iowa purchased 10 percent of their produce items locally, found that the conventional food system emitted 5 to 17 times more carbon dioxide than purchasing locally (Pirog *et al*. 2001). Research shows that purchasing locally may be even more important than purchasing organically, in terms of the environmental benefits (Pretty *et al*. 2005).

According to the U.S. Department of Energy, in 2005, transportation accounted for 33 percent of carbon dioxide emissions in the United States. Emissions in the transportation sector have increased 24.8 percent since 1990 and have grown more than any other sector (Davies 2006). Although specific statistics for the percentage of overall transportation used for food distribution are not available, Hendrickson calculated that the food sector made up 16 percent of US energy consumption, with transportation accounting for 11 percent of the food sector's energy consumption (Hendrickson 1996). This number is likely higher now with increased trucking and food production over the last decade. From 1992 to 2002, the number of trucks in the US increased by 43 percent, for a total of 8.5 million trucks in 2005 (US Dept. of Transportation). Similarly, there has been an increase in vehicle miles traveled, with the number of miles traveled by trucks in the US increasing by 4.9 billion miles from 2003 to 2005 (US

Dept. of Transportation). Superfluous trade, where very similar or identical products are imported to and exported from the same place unnecessarily, also contributes to high energy consumption, food miles and emissions in the global food system. For example, the New York City port exports $ 70,000 of California grown pistachios a year to Italy, while also importing $50,000 worth of Italian grown pistachios to the US (Mamen *et al.* 2004).

With rising concerns over global warming, and the link between fossil fuel consumption and transportation of food, many researchers have been focusing more attention on energy usage in food systems. There have been contradictory conclusions regarding the assumed reduction in total energy used for food transportation in local food systems and the environmental benefits of such. Proponents of conventional food systems state that large scale distribution is more efficient and uses less total fuel for transportation due to a higher load capacity per truck (Wallgren 2006). A study conducted in Stockholm, Sweden found that although food purchased in local food systems traveled many less miles, there was no reduction in the total energy used because of high loading capacity in conventional food systems (Wallgren 2006). Similarly, a study in Flanders, Belgium found that on average more energy was used, and more carbon dioxide emitted, in a typical "meal" purchased through a local food system than a conventional supermarket (Van Hauwermeiren *et al*. 2007). A report prepared for the Department of Environment, Food and Rural Affairs (DEFRA) in the United Kingdom, found that the distance that a food item travels is not necessarily reflective of the energy burden caused by that item (Smith *et al*. 2005). They presented a case study comparing UK tomatoes grown in a heated greenhouse with outdoor grown tomatoes imported from Spain, where the carbon dioxide emissions were 2394 kg/ ton tomatoes and 630 g/ton respectively.

Although these studies provide valuable information about issues to consider and suggestions on how to increase efficiency in local food systems, it is important to consider that the conventional food systems (as well as the local food systems) may be configured differently in different places. Therefore, in some places local food systems may be more efficient than conventional food systems or vice versa. An energy consumption study has not been conducted for the transportation of food within local and conventional food systems in the United States. Considering the size of the country, as well as the structure and size of distribution areas for national chain supermarkets, it is very important to conduct a study comparing the total energy used in transportation of food in local and conventional food systems in the United States.

This study will seek to answer the question of energy consumption in the transportation of food in local and conventional food systems in the context of the American food system. Berkeley, California will serve as a case study for this comparison of conventional and local food systems in the American food system. Similar to many highly urbanized areas in the United States, Berkeley is located near productive farmland that serves as the source of food for local food systems. Berkeley is located less than 200 miles from the Central Valley of California, the United States' largest agricultural producer. This makes Berkeley an excellent example of the potential of local food systems. While the ability to purchase locally grown produce year round due to a Mediterranean climate is unique when compared to most of the United States, California produce is found year round throughout the country. Therefore, conventional food systems outside of California may have even higher energy burdens associated with them. Farmers' markets and other ways to distribute food through local food systems are becoming popular all over the United States, and the results of this study will be particularly important when food items are available through both food systems at the same time.

This study will specifically research the total energy used in the transport of food from the producer to the place of purchase for food sold at farmers' markets and conventional supermarkets in Berkeley, California. At a farmers' market, representatives from farms bring produce and food items directly from the place of production to a central place within Berkeley for consumers to purchase. The distance is no more than half a day drive, with driving distances typically ranging from 70 miles to 200 miles. I hypothesize that food sold at farmers' markets will consume less energy for transportation, due to closer distances to the consumer and a lack of intermediary distribution centers. Through interviews with farm representatives at farmers' markets and purchasers for supermarkets, transportation data for specific food items will be gathered in order to calculate the total energy consumed in the transportation of each food item.

Methods

Interviews with farm representatives at farmers' markets and purchasers for supermarkets were conducted in Berkeley, California from January 2008 to March 2008 at the Berkeley Farmers Market and various conventional supermarkets located within Berkeley. At the Berkeley Farmers Market, representatives from farms bring produce and food items directly from the place of production to a central place within Berkeley for consumers to purchase. The distance is no more than a half a day drive, with driving times typically ranging from 2 hours to 6, making the Berkeley Farmers' market fit the criteria for a local food retail outlet. It is held 4 hours a day, every Tuesday, Thursday, and Saturday, year round in three different outdoor locations throughout the City of Berkeley. Farms represented may vary at each market, with various farms participating in one to all three of the markets every week. However, for a given market day, the individual farms represented stays relatively constant, as farms must apply to the Berkeley Ecology Center in order to sell at the market. In this study, conventional supermarkets were defined as "one-stop" markets selling a variety of products, with a parking area and open at least 6 days a week. Chain supermarkets with national distribution systems, as well as independent supermarkets were sampled and tested to see if any differences in energy used for transport of food existed between different types of supermarkets.

Interviews were chosen as the basis for this study because, due to the complex nature of food systems, this type of data was not recorded or available anywhere else. People involved with the packing, transport, distribution and sales of food are the experts in this field, and therefore were the subjects of my interviews. By doing primary interviews, I was able to cross check and verify the information I received from the subject by looking at the vehicles, the boxes, the food itself, and any other signs that provided information about the origin and transportation of the produce.

Interviews were conducted with farm representatives and farmers at the Berkeley farmers market, as well as produce buyers, produce managers, and truck drivers at conventional supermarkets. During the interview I collected data regarding the transportation of a specific food item from the place of production to the place of purchase. This data included, the place of production, path to the place of purchase, mode(s) of transportation, the use of refrigeration, pounds of food transported in each stage, and type of fuel used (see appendix 1 for complete interview questions). Interviews were conducted at the farmers market and the individual supermarkets while each subject was working.

The transportation data I collected at the interview was then used to calculate the total energy used per kilogram of food in the transportation of each item. Energy used in transportation is a function of the distance, the fuel economy, and the energy content of fuel used (Wallgren 2006). The fuel economy is a function of mode of transportation, age and model of vehicle, driving pattern, speed, vehicle load, and refrigeration use (Jones 1999).

E = energy used per kg for each stage in transportation = (d x 1/f x c)/ v

(where d = distance, f = fuel economy, c = energy content of fuel, v= vehicle load in kg)

f = fuel economy= fcn(mode, age, model, driving pattern, speed, load, refrigeration use)

E_T = total energy used per kg during transportation= $\sum E$

The driving distance was calculated based on driving directions from the most exact information I was able to obtain during interviews for the location of production, to the location of purchase from “maps.google.com”. For international road transportation, the distance was calculated using an international road atlas. By studying the map and researching the most common truck routes, the most likely distance traveled by the truck was calculated. A string was used to trace the route and then converted to kilometers using the given scale of the map. If the transportation involved overseas travel, the distance was calculated based on the available published shipping lane data from USGS topographic maps. If the transportation involved air travel, the distance was calculated “as the crow flies”, or straight line, from the most exact information we were able to obtain during interviews for the location of production, to the location of purchase. This distance was calculated using “Google-Earth.” Although, flight paths are not necessarily straight lines, in the long distance flights (usually over water) when food is being transported in planes, the flight paths most closely resemble straight lines. After comparing a published flight path distance from Chile to San Francisco with the “Google- earth” method, the two methods differed by 9 km in the 10,000 km trip.

The energy content of fuels was taken to be the standards of 124,000 Btu/ gallon for gasoline, and 139,000 Btu/ gallon diesel fuel, which were then converted to kilojoules. The fuel economy for gasoline vehicles was found at the US Department of Energy’s database for fuel economy of various vehicles (http://www.fueleconomy.gov/feg/findacar.htm). For this study, the highway fuel economy was used. As seen on the driving directions, as well as what is typical of long distance freight travel, most transportation occurs on highways. If a vehicle used in transportation was not found on the database, averages for vehicle type were used (car, pickup truck, light truck, etc) (see appendix 2). For diesel trucks, averages of six miles per gallon for heavy duty fright trucks and 8.5 miles per gallon for midsize trucks were used (Pirog et al. 2001).

According to Jones (1999), refrigeration in road fright consumes 0.16-0.46 MJ/ tonne/ km. In this study, the mean value, 0.31 MJ/ tonne/km was used. However, to be sure that the use of the mean did not skew the results, calculations were carried out using both the lower and upper bound of the range and compared to see the impact that the efficiency of refrigeration has on total energy consumption in transportation. Although the driving pattern, speed, and load contribute to fuel consumption, for the purposes of this study, I assumed that the average fuel economies take into account average behavior for these characteristics. Furthermore, since I was concerned with a difference between the two food systems, and these factors would affect both local and conventional food systems in the same way, the results are not changed if these factors are ignored. The vehicle load was obtained through interviews. If the transportation of a food item involved more than one stage or mode of transportation, the total energy used in each stage was calculated according to the equation, and summed.

Transportation data was gathered for ten different commonly consumed food items that were available at both the Berkeley Farmers Market and conventional supermarkets in Berkeley during the time that research was being gathered. The most similar, including specific varieties, of food items were compared, and data was gathered at farmers' markets and supermarkets for each item within 3 days, to make sure changes in season do no effect results. Since most of the food items being sold at the farmer's markets were organic, most of the produce compared was certified organic. Five supermarkets were sampled, as well as all farms selling the specific item. The number of farmers selling specific items ranged from one to four, with an average of two farms selling each item. This resulted in a total sample size of n=49 for supermarkets, and n=38 for the farmers market. The average total energy for each item was compared, as well as the average total energy for the combination of all the items. After log transforming the data to account for deviations from a normal distribution, a t-test was used to evaluate the statistical significance of the difference in energy use between the supermarkets and farmers' markets.

To evaluate factors that may be contributing to variations in the efficiency, particularly at the level of the local food system, secondary data was also gathered. This data included farm size, volume sold daily, number of years in production, number of acres in production for the specific item, number of crops grown on the farm, and time period for selling the specific item. Although, this type of data was attempted to be gathered for the conventional food system, it was difficult to obtain. However, due the large scale of commercial agriculture and the typical farm characteristics of farms selling to supermarkets in the conventional food system, these factors played less of a role in the efficiency of the transportation of food items.

Results

Data analyzed found no statistically significant difference between the energy used in the transportation of food in conventional and local food systems. Therefore the hypothesis that local food systems would use less total energy in the transportation of food from the place of production to the place of purchase was not supported by this study. Food items from the farmers market consumed on average more energy (1.54 kJ/kg food ± .222 kJ/kg, n=38) (mean ± S.E.) for transportation than did food items from conventional supermarkets (.861 kJ/kg food ± .0717 kJ/kg, n= 49) (Fig. 1). However, this difference was not found to be statistically significant (t= 1.28, df = 58.1, p= .1022) to an acceptable confidence interval of five percent (or p= .05).

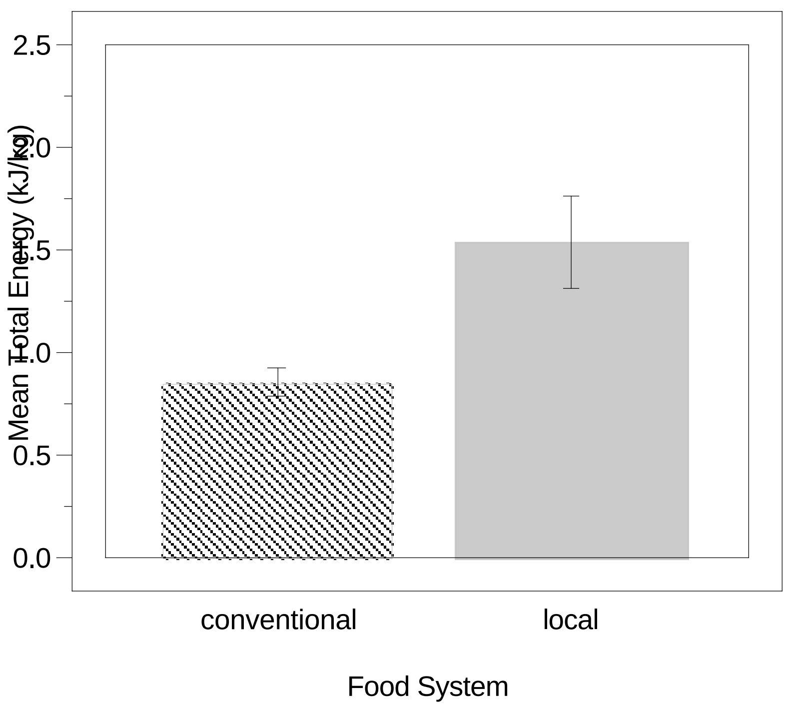

Figure 1. Average energy use (± S.E.) for transportation in local (n=38) and conventional (n= 49) food systems in Berkeley, CA. The difference was found not to be statistically significant (t= 1.28, df = 58.1, p= .1022).

The energy used per kg of food in the local food system ranged from .263 kJ/kg food to 5.54 kJ/kg, while the range for the conventional food system was .143 kJ/kg to 2.33 kJ/kg. Distance ranged from 73 to 200 miles in the local food system and 83 to 1,364 miles in the conventional. Vehicle loads ranged from 181 kg to 4545 kg in the local food system and 1363 kg to 17,272 kg in the conventional food system. The energy use in transportation varied by item (Figure 2), with organic celery and organic navel oranges showing the largest difference in energy use between the two food systems. The only statistically significant difference in energy consumption for transportation between local and conventional food systems for specific items was found for organic celery (t= 2.94, p= .0213, DF= 3.98). Only for yellow potatoes, did the farmers market on average use less energy for transportation than through the conventional food system.

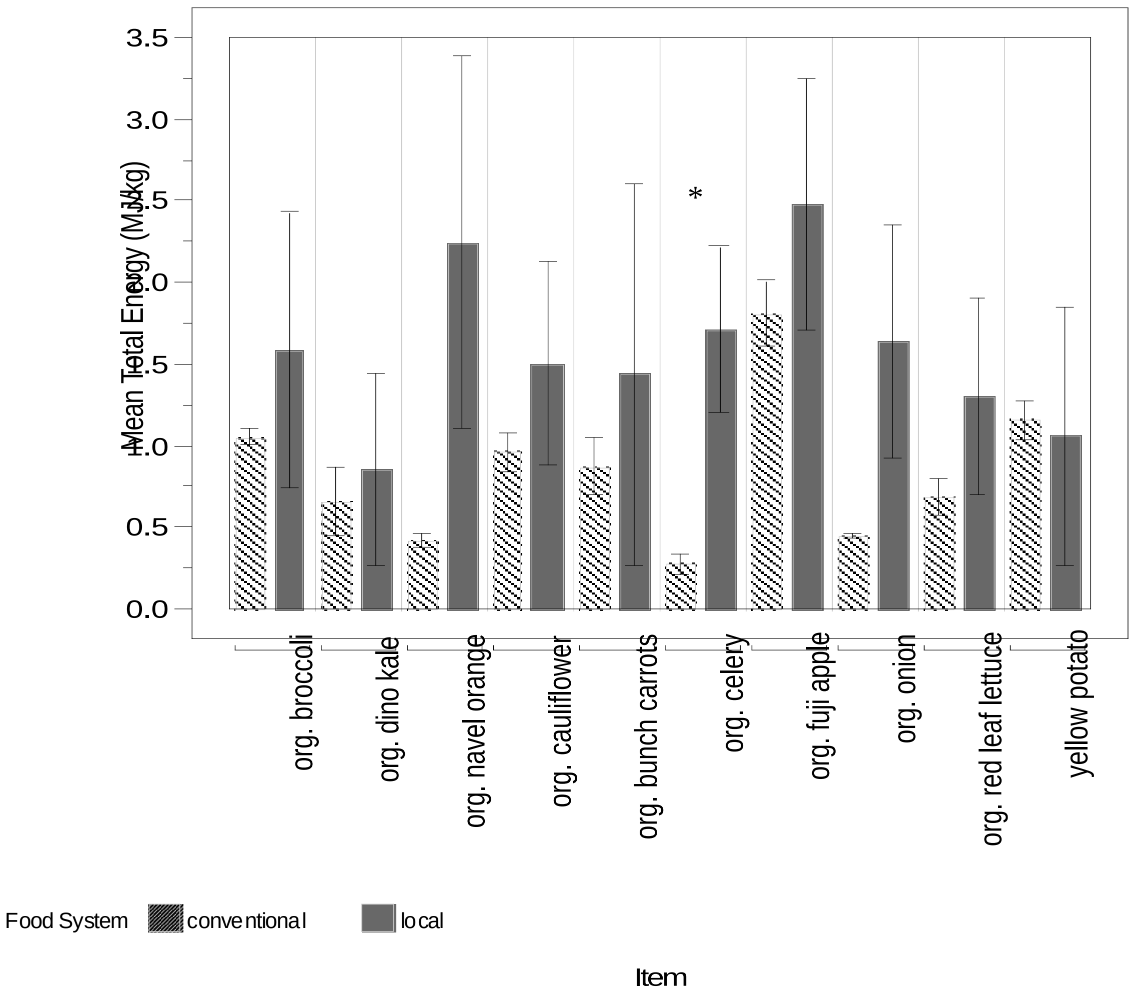

Figure 2. Average energy use (and standard error) in the transportation of different food items in local and conventional food systems in Berkeley, CA. (* indicates statistical significance).

In order to evaluate which factors were responsible for the variability in energy use within food systems, regressions were done on the total energy and the various factors that may contribute to higher energy use. Of all the factors included in this study, the most important factors that contributed to energy use in local food systems were the vehicle load and number of different items being sold by the farm representative (Table 1). Regression analysis indicated that total energy use per kg of food in transportation was negatively correlated with the number of items being sold by the farm representative (R^2 = .342, p <.0001) and also with larger loads (R^2 = .756, p<.0001). The factors that most influenced energy use in the conventional food system were distance (R^2 = .978, p <.0001) and refrigeration distance (R^2 = .661, p <.0001) (Table 2), which were both positively correlated. No statistically significant differences were found for the average transportation energy for the different stores sampled in the conventional food system, indicating that the type of conventional store had little affect on the energy used in transportation.

Table 1. Factors contributing to energy use in the transportation of food in local food systems.

Regression of total energy used on:	R^2 value	P value	y equation
	.756	<.0001	y = 9090 - 2745 x
Vehicle Load			
Number of items being sold	.342	<.0001	y = 15.1 - 1.69 x
Farm Acreage	.144	.0188	y = 106 - 22.7 x
Fuel efficiency of vehicle	.0300	.339	y = 11.2 + 0.411 x
Distance traveled from place of production to purchase	.0255	.338	y = 89.3 + 2.24 x

Table 2. Factors contributing to energy use in the transportation of food in conventional food systems.

Regression of total energy used on:	R^2 value	P value	y equation
	.978	<.0001	y = -.895 + 600x
Distance traveled from place of production to purchase			
Refrigeration distance	.661	<.0001	y = -51.3 + 520x
Load	n/a (no variability)	------	------
Fuel efficiency	n/a (no variability)	------	------

Discussion

Energy use in the transportation of food from the place of production to the place of purchase in local and conventional food systems was evaluated using examples of food items from farmers markets and supermarkets in Berkeley, CA. Results of this study indicated that there was no difference in transportation energy use for food purchased at farmers markets and supermarkets. Although on average the food items sampled at the supermarkets, which represented the conventional food system, used less energy in their transportation to the place of purchase than did items sampled at a local farmers market, the difference was not statistically significant. These findings did not support the hypothesis that due to closer distances and a lack of distribution centers, food bought from local farmers markets would use less energy in the transportation of food. Nevertheless, the results of this study brought forth important observations about energy efficiency in both types of food systems.

The calculated transportation energy for the local food system from the farmers market data had a very large standard error (1.36 compared to .499 for the conventional), showing the large variation in energy use in transportation of food through local food systems. This large variation in the energy efficiency of transportation of food in local food systems is a very important result of this study, and it may be related to a lack of statistically significant findings. Regressions on total energy used in transportation and many factors that may determine energy consumption found the vehicle load in vehicles going to the farmers market played the largest role in determining variable energy use within the local food system. It is the large spread in vehicle loads that ultimately created the large variation in total energy use, which made it difficult to draw statistically significant conclusions.

In contrast, the data gathered for the conventional supermarkets was much less variable. This is in part due to the assumption that all large semi-trucks used in food transportation in the conventional system were filled to capacity at 17,270 kg with a fuel economy of 6 mpg unless otherwise stated. Although these assumptions were supported by other sources as reasonable, no primary data was obtained on the actual loads of the trucks and actual truck loads could be filled below capacity. These assumptions could also be the reason that no statistically significant differences were observed for the energy used in transportation between the different types of stores sampled. Smaller truck loads could potentially be seen on shorter trips made daily to supermarkets from distribution centers and wholesale warehouses. As seen with the impact that vehicle load had on the energy use in the local food system, if found to be different, the assumption about vehicle load could drastically change the energy used per kg of food in transportation and alter the results of this study.

The results found in this study were very similar to those found by Wallgren (2006) in Sweden. Wallgren concluded that there was no significant difference in energy consumption in the transport of food between farmers markets and conventional food systems. Similarly, Wallgren relied on assumptions from life cycle assessments about the load capacity of trucks carrying produce in conventional food systems. Therefore, if these assumptions were inaccurate, both studies may have been impacted in similar ways. In contrast, Van Hauwermeiren *et al*. (2007) found local food systems to use more energy. A larger difference between the two food systems (5.25 kJ/kg for local versus 1.60 kJ/kg for conventional) was found in Van Hauwermeiren's study in Belgium. One reason for this is that Van Hauwermeiren's study assumed that the conventional food items were originating in the same location as the local ones. However, as many large scale growers rotate production to different climates throughout the grower season, this assumption is not justified. In addition, Van Hauwermeiren also mentioned the assumption of vehicle loading capacity and the potential that real loading capacity may vary greatly. Pirog *et al.* (2001) found opposite results for a comparable study, in which local food systems had the potential to greatly reduce energy consumption. However, Pirog's study was based in Iowa, where practically all of the conventional produce was traveling 1,700 miles or more from California.

This would suggest that when the consumer is far from the place where conventional food items are produced, decreasing the distance food travels through local purchasing would greatly reduce the energy for transportation when compared to the conventional food system. In this case, the efficiencies in large conventional vehicle loads are trumped by the inefficiencies in long distance travel with low fuel economies. There is a point where, even with the current design of farmers markets, with some loads smaller and less efficient than others, that the inefficiencies in the conventional food system no longer are made up for by the larger load capacity, and farmer's markets becomes more efficient. This distance from the place of production to the consumer where conventional food systems no longer use on average less energy would be an important area for further research.

Long distance was observed to be the greatest contributor to high energy use in the conventional food system in this study. That being said, it is important to note that in Berkeley, many of the items that were compared in this study were produced very close to the origin of the conventional food items (California and the Southwestern United States) and the high load capacity efficiencies that are assumed in the conventional food system are taken advantage of. This may explain why I found the conventional food system to be more efficient when compared to the current design of the farmers' markets as an outlet for local food systems.

Therefore, in some places, including Berkeley, eating only items that are grown seasonally in the same region as the consumer, and thus reducing imports and the distance that food travels, may be an even more important factor than purchasing through the local food system in reducing the average energy used in transportation and the carbon footprint of one's diet. To evaluate the impact that long distance travel has on the efficiency of the conventional food system, it would be an interesting study to compare the energy consumption for transportation of in-season local food items with out of season conventional food items. This type of study could also capture the fluxuating efficiency of the conventional food system as productions shifts to different areas (further from the place of consumption) based on seasons. Nevertheless, by maximizing load capacities in the local food system, energy use in the transport of food will be decreased when compared to the conventional food system, which will be true even in Berkeley, as the distance traveled is reduced (even slightly) from the conventional food system (with distribution centers and multiple stages of transport). This energy efficiency in the local food system was observed in this study when some farmers, carrying large loads of produce, used well below the average energy use for transportation in the conventional food system.

Clearly, Berkeley's location is very unique and its proximity to the heartland of the conventional food system and rich year-round agricultural production makes it an anomaly in the context of the American food system. The Mediterranean climate and year- round production produces an abundant variety of produce for American consumers, as well as people in California looking to support local agriculture. In most other places in the United States, the opportunity to purchase a wide variety of locally produced foods year -round is not available. However, as this study evaluates only items that are available both locally and conventionally at the same time, the results are still applicable to other part of the country and are most important when a consumer has a choice between local and conventional food. Furthermore, as pointed out earlier, in places further away from the heartland of the conventional food system, transportation energy most likely is decreased (depending on vehicle loads and efficiency in the local food system) by purchasing locally when that choice is available. Similarly, in places that do experience shorter growing seasons and large temperature changes over the course of the year, it is still important to consider seasonality when purchasing. Although one of the most hailed features of the conventional food system is the ability to provide a wide variety of produce year-round to every region in America, emphasizing local and seasonal purchasing, even for a few months on the margins of the growing seasons in these areas, will help reduce the energy use in the American food system.

An important theme found in this and comparable studies is the importance of a full analysis of food systems and the energy consumption associated with them, in respect to specific locations, infrastructure and the context within which the food system is running. Therefore, although this study did successfully analyze local and conventional food systems in the context of an American food system, particularly in Berkeley, CA, there are many factors that vary among every food system. The results of this study did not support the hypothesis that local food systems reduced the energy consumption in the transportation of food. However, there are many different forms of local food system distribution, including community supported agriculture, large scale distribution (directly to retailers and institutions) and collaborations of local growers. This study did not evaluate the energy intensities of these outlets for local foods, whose potential for larger loads makes these outlets promising to reduce energy use in transportation. Furthermore, although there are similarities between many typical conventional American food systems, different regions in the United States have food systems configured differently. Specifically, California is the number one agricultural producer in the country, producing half of the nation’s fruits, vegetables and nuts (USDA). This indicates that food items are traveling much farther through conventional food systems to most markets than they traveled to Berkeley, CA, the location of this study. Although the food systems providing for the residents of Berkeley, CA are part of a larger American food system, there are important differences to consider when comparing the energy intensities of local and conventional food systems, as they may be configured differently around the nation.

As demonstrated by the complexity and uniqueness of food systems, both conventional and local, the results of this study provide leads for further research into the question of energy usage in the local and conventional food systems. Specifically, the energy efficiencies of local and conventional food systems should be evaluated in different areas, particularly in places like the Midwest and East Coast of the United States, where even when local produce is available many food items are still trucked across the country. Furthermore, it is clear from the results of this study and the incidence of farms bringing only a fraction of the vehicle capacity's worth of food, that there are inefficiencies in the farmers markets. Therefore, it is extremely important to look into other types of distribution for local food, as well as the load capacities that are needed in order to increase the energy efficiencies of farmers markets. Similarly, in conventional food systems there are still many areas where energy efficiency could be further evaluated, including the excess distance that food is traveling when it is available closer to the place of consumption. The load capacities that are observed in reality versus the assumptions of full loads that were used in this study are also an important area of research, as the load capacity is responsible for the efficiency of conventional food systems. Finally, transportation from the place of production to purchase is only one part of the energy consumed in the entire food system. Methods of production, processing, storage, preparation, and disposal of wastes may differ between local and conventional food systems, resulting in different amounts of energy consumed in the overall production and consumption of food. It is important to consider the entire process when evaluating energy use in different food systems and full life cycle assessments are an important tool to do this.

This evaluation of energy use in the transportation of food in local and conventional food systems identified places of inefficiencies in both food systems. The identification of places of inefficiency is the first step in creating systems that are more efficient. Therefore, although the current design of farmers markets may not be on average the most energy efficient outlet for local food systems, farmers markets and other distribution schemes for local food have potential to greatly reduce energy consumption in the transportation of food. Farms that transported large enough amounts of produce in their vehicles did show a reduction in energy use when compared to food items traveling through the conventional food system. For this reason, new designs of farmers' markets that include cooperative transport and maximizing vehicle loads should be a priority. Similarly, other types of distribution for local foods, including larger scale distribution involving direct marketing to schools, hospitals, other institutions and retail outlets have a lot of promise to reduce energy consumption in the transport of food. Furthermore, as interest in local food continues to grow for a variety of important reasons, not just for a reduction in the energy use in transportation, the capacity for efficiency will further increase. The results of this study have identified the places of inefficiency and a potential for great efficiency in the use of farmers markets as an important food outlet in local food systems.

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Appendix 1: Interview questions

Farmers' Market Interview

1. Where is this item produced?
    a. What is the address of the farm?
    b. What is the nearest town or city?
    c. Nearest cross street?
    d. Any other identifying location information?
2. How many total acres is the farm?
3. How many total crops are grown in a given rotation?
4. How many weeks per year is it sold at market?
5. How many pounds of this item did you bring to market today?
    a. Last week?
    b. The week before that?
6. Is this typical of this item?
    a. Is this a good season/bad season/ atypical/ typical?
    b. Please explain more.
7. How many years have you been planting/ harvesting/ producing this product? Is the production at its maturity?
8. How many acres do you have planted of this item this year?
    a. How many times per week do you harvest?
    b. How much do you harvest each time?
    c. How much of this is sold at farmers' markets?
    d. This farmers' market?

9. Please describe the path that the item takes from the farm, to here where I can purchase it.
    a. What is the process and mode of distribution?
    b. Are there any stops? If so, where? For how long? Where did the food go during that time?
10. What is the mode of transportation in each step?
    a. What is the make/model/year of vehicle, type of airplane or boat?
    b. Does the vehicle have to go through the CA smog emissions test?

c. What year was it last tested and passed?

d. What type of fuel is used?

11. How long does it take to get from the place of production to here where I can buy it?

    a. Is there usually traffic?

    b. For how long?

12. Is refrigeration used during any part of transportation?

    a. For how long? Distance, time…

    b. Why?

13. How many pounds of food were carried in the vehicle?

14. How much of this load did this item make up?

15. What is the maximum capacity of this vehicle?

    a. Was the vehicle full this week?

    b. Was it full last week?

    c. How much room was left?

16. Was there anything else transported in the truck?

    a. Where is that going?

    b. How much is it?

17. Do you usually sell all of this product at the market?

    a. How much do you usually have left over?

    b. What happens to that product?

    c. Is it transported somewhere? Where?

    d. What happens to it when it gets there?

Conventional Supermarket Interview

1. Where is this item produced?

    a. What is the address of the farm?

    b. What is the nearest town or city?

    c. Nearest cross street?

    d. Any other identifying location information?

2. Does this change over the year?

3. Do you sell this product all year round?

   a. How many weeks per year?
4. How much do you sell daily?
   a. Today?
   b. Last month?
   c. 5 months ago?
5. Is there usually any waste or food thrown away?
   a. How much?
6. Describe the path that the item takes from where it is produced to where I can purchase it?
   a. What is the process and mode of distribution?
   b. Are there any stops? If so, where? For how long? Where did the food go during that time?
7. What is the mode of transportation in each step?
   a. What is the make/model/year of vehicle, type of airplane or boat?
   b. Does the vehicle have to go through the CA smog emissions test?
   c. What year was it last tested and passed?
   d. What type of fuel is used?
8. How long does it take to get from the place of production to here where I can buy it?
   a. Is there usually traffic?
   b. For how long?
9. Is refrigeration used during any part of transportation?
   a. For how long? Distance, time…
   b. Why?
10. How many pounds of food were carried in the vehicle?
11. How much of this load did this item make up?
12. What is the maximum capacity of this vehicle?
   a. Was the vehicle full this week?
   b. Was it full last week?
   c. How much room was left?
13. Was there anything else transported in the truck?
   a. Where is that going?

b. How much is it?

Questions for Conventional Farms

1. Is this item grown all year round?
    a. How long
2. How many acres of this crop do you grow?
3. How many crops are in rotations on this farm?
4. How many years have you been producing this item?

Appendix 2: Average Fuel Economies used

Type of Vehicle	**Fuel Economy**	**Source**
Passenger car	21 mpg	www.bts.gov (US Bureau of Transportation Statistics)
Light gasoline truck	17.2 mpg	(Pirog et al 2001)
Other 2 axle, 4 tire vehicle	17 mpg	www.bts.gov (US Bureau of Transportation Statistics)