Fossil Fuel Energy Use for Meat in New York City

Michael Minn

Hunter College - Department of Geography

30 June 2009

Introduction

In considering the sustainability and resiliency of cities, it is helpful to assess the environmental impact of specific areas of consumption and lifestyle. America's comparatively high level of meat consumption has been decried for its environmental impact. The complete dependence of industrial meat production practices on fossil fuels is of particular concern as world supplies of fossil fuels begin to dwindle and as the use of those fossil fuels contributes to potentially catastrophic climate change (Eshel and Martin 2006, Pimentel and Pimentel 2003).

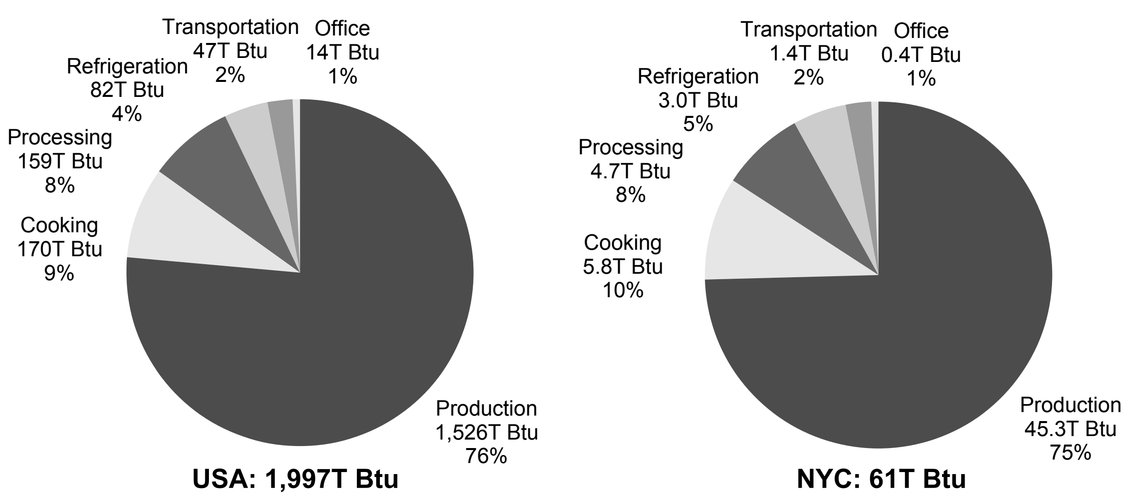

Figure 1: Energy Use for Meat in the U.S. and NYC

The following paper details the estimated 61 trillion British Thermal Units (Btu) of "embedded" fossil fuel energy required per year to raise, process, transport, store and prepare meat for consumption by residents of New York City (NYC). Total meat energy use for the entire United States is estimated at 2,000 trillion Btu. The focus is on the three most common meats (beef, chicken and pork), with very limited discussion of lamb and seafood. No consideration is given to less-common or "exotic" meats like goat or buffalo.

This analysis works backwards from city consumption to points of birth and processing using publicly-available government and industry data. There do not appear to be any reliable studies providing exact information for the amount of meat consumed in NYC or the specific origins of that meat. Therefore, statistical information in this paper is often inferred or interpolated from numbers that use higher levels of aggregation. Limitations of the data make it impossible to specify exact energy amounts with complete certainty, but it is possible to make educated guesses that can be used for comparison with figures for other food and non-food energy uses.

Energy Use in New York City

Energy values in this paper are expressed in Btu to permit ready comparison with figures commonly provided in that unit by the energy industry and by federal agencies that monitor American energy use and policy. Because the Btu is a fairly small unit (the amount of energy needed to heat one pound of water by one degree), values in this paper are generally specified in trillions of Btu, which is abbreviated by appending the letter "T" to values (e.g. 18.3T Btu = 18,300,000,000,000 Btu).

Btus are converted from Joules (commonly used in scientific literature) and kilo-calories (aka food "Calories") using the conversion factors 1,055 J / Btu and 0.252 KC / Btu, respectively. Electricity use is converted from kilowatt-hours (kWh) using a fossil-fuel heat rate of 9,919 Btu / kWh, which reflects the considerable losses (around 66%) in production and transmission of electricity generated from fossil fuels (EIA 2009a). Table 1 gives some other illustrative estimates of fossil-fuel energy end-uses in NYC for comparison.

	USA	NYC	NYC Per Capita	Source
Street and Traffic Lighting		3.9T Btu	466,300 Btu	(NYCEPTF 2004)
NYC DEP (water and sewage)		6.3T Btu	753,254 Btu	(NYCEPTF 2004)
Universities, Libraries and Cultural Institutions		6.4T Btu	765,211 Btu	(NYCEPTF 2004)
Elementary / Secondary Schools		8.8T Btu	1,052,165 Btu	(NYCEPTF 2004)
Meat	1,997.1T Btu	60.8T Btu	6,475,000 Btu	(Minn 2009)
Indian Point Total Generation		167.0T Btu	19,967,216 Btu	(EIA 2008c)
Res/Comm Building Natural Gas Use	8,221.7T Btu	232.0T Btu	27,738,886 Btu	(conEdison 2009b)
Food	10,463.4T Btu	287.8T Btu	34,412,416 Btu	(Heller & Keolein 2000)
Heating Oil Consumption	1,112.9T Btu	422.0T Btu	50,456,078 Btu	(PlaNYC 2007, 102)
Electricity Consumption	36,918.5T Btu	544.0T Btu	65,042,906 Btu	(conEdison 2009a)
Total Natural Gas Use (building + generation)	23,914.0T Btu	699.0T Btu	83,575,351 Btu	(NYCEPTF 2004, 17)
Total 2008 US Energy Usage	99,300.0T Btu	2,731.4T Btu	326,580,577 Btu	(EIA 2009a)

Table 1: Examples of Energy Usage in New York City

Population

Meaningful statistics on meat consumption specifically for NYC do not appear to exist and this is an area that remains to be researched more fully. However, there are nation-level statistics for meat consumption and production and it seems reasonable to assume that per capita consumption levels at the city level would similar to those at the national level. Therefore, in this paper, the amount of meat consumed by NYC residents is assumed to be a percentage of national consumption equivalent to the percentage of national population.

The United States Census Bureau (USCB) estimated that in July of 2008, the population of the United States was 304,059,724, the population of New York State was 19,490,297, and the population of NYC (all five boroughs) was 8,363,710 (USCB 2008, NYCDCP 2008). This gives NYC around 2.75% of total U.S. population and New York State around 6.41%.

While these population numbers may seem fairly straightforward, NYC is an internationally significant destination that is an annual host around 45 million tourists (NYC&CO 2008). NYC is also the workplace of 800,000 commuters from Long Island, New Jersey, Westchester County, Connecticut and Rockland County (Herszenhorn 2002). Since these non-residents eat while visiting, their additional load to the NYC food ecosystem should be considered. Domestic tourist and commuting numbers represent a direct transfer of food demand from their resident communities to NYC. International tourist numbers might be considered to be incomparable with overall U.S. population numbers since the overall numbers do not included tourists. However, while the U.S. hosted 56 million international visitors in 2007, it also sent around 40 million visitors to overseas destinations (OTTI 2009), making the cumulative effect on U.S. population less dramatic. These numbers and their annualized effect are detailed in table 2.

Of somewhat greater significance (and uncertainty) may be the additional food demand associated with unauthorized immigrants. There are an estimated 12 million unauthorized immigrants living in the United States (Passel 2009, 1). New York City has for centuries been a magnet for immigrants and remains so for an estimated 535,000 unauthorized immigrants or 4.5%, of the estimated unauthorized immigrant population of the United States (FPI 2007, 21). Because it is uncertain how many of these undocumented residents are factored into USCB population estimates, they are considered as additions in table 2.

	Persons	Avg. Stay	Hrs/Day	Annualized
NYC Residents (2008)	8,363,710			8,363,710
Undocumented Residents	535,000			535,000
Domestic Tourists	37,100,000	2.2 days	24	223,616
Int'l Tourists	7,650,000	7.3 days	24	152,874
Commuters	800,000	250 days	8	182,498
Reverse Commuters	300,000	250 days	8	(68,437)
NYC Total				9,389,262
U.S. Residents (2008)	304,059,724			304,059,724
U.S. Undocumented Residents	12,000,000			12,000,000
U.S. Total				316,059,724
NYC percent of U.S.				2.97%
NYC percent (census only)				*2.75%*

Sources: Passel 2009, FPI 2007, NYC&CO 2008, OTTI 2009 Herszenhorn 2002, Fessenden 2008.

Table 2: Adjustments to NYC Population for Visitors and Undocumented Residents

Meat Consumption

This paper operates under the assumption that New York City's per capita meat consumption is roughly equivalent to the rest of the country and that (on a percentage basis using the adjusted population figures above) New York City's share of national meat consumption is 2.97%. There is likely some discrepancy between this assumption and actual values due to unique qualities of urban lifestyles, the high density of wealthy residents in parts of the city and the influence of the diverse world cultures represented by the city's population. These may be reflected in higher levels of vegetarianism, preferences for different cuts or grades of meat, avoidance of certain animals for religious reasons (like pork and shellfish) or the serving of meats (like lamb and goat) that are not common in the diet of the general U.S. population. However, exploration of these cultural nuances and other demographic idiosyncrasies is beyond the scope of this document and is left for future dietary researchers.

The United States Department of Agriculture's Economic Research Service (ERS) provides estimates of "availability" and "disappearance" for a number of food commodities. The use of disappearance figures are valuable in that they account for all meat that is made available for use, regardless of whether it is consumed or wasted. ERS availability figures also include imports from other countries and exclude exports of domestically produced foods to foreign markets. The figures (except for fresh/frozen seafood) do not account for whether the product is made available fresh or as a component of some processed product (like canned soup or beef jerky). Table 3 details U.S. meat, poultry and seafood availability in 2007 with approximate figures for New York state and NYC based on population percentage.

The American Meat Institute (AMI) provides figures for the number of animals grown by American meat producers. Subtracting export figures from the USDA, figure 4 gives estimates of the number of animals slaughtered in 2007 to provide meat and poultry to NYC. This works out to around 26 animals annually slaughtered for each resident of the city.

Levay (2009) came up with similar estimates of 258 tons of retail beef and 167 tons of retail pork annual disappearance in NYC. However, using an average yield of 492 pounds of boneless, trimmed meat from one steer and 118 pounds from one hog, Levay came up with somewhat higher animal count estimates of 1,049,452 cattle and 3,260,725 hogs per year. It is not known whether this reflects problems with the AMI figures, accounting for additional meat products extracted from carcasses that are not considered in Levay's trimmed meat statistics, or some unknown factors associated with meat processing.

Residential and Commercial Sector Energy Use for Meat

Most fresh foods that are not consumed promptly after harvesting require some level of refrigeration to prevent spoilage. Fresh animal-based products are especially dependent upon refrigeration since micro-organism growth can cause severe illness or death in humans (PUASD 2009). Also, Americans rarely consume meat without cooking it first. Therefore, energy use for storing and cooking meat must be considered when evaluating the total energy life-cycle of meat consumption.

	US	NY State	NY City
Adjusted Population	316,059,724	19,490,297	9,389,262
	100%	6.17%	2.97%
Young Chicken (carcass)	14,864,313 tons	916,630 tons	441,578 tons
Young Chicken (retail)	12,768,445 tons	787,385 tons	379,315 tons
Young Chicken (boneless)	8,948,317 tons	551,811 tons	265,830 tons
Beef (carcass)	14,020,996 tons	864,626 tons	416,525 tons
Beef (retail)	9,814,698 tons	605,238 tons	291,568 tons
Beef (boneless)	9,380,047 tons	578,435 tons	278,655 tons
Pork (carcass)	9,781,489 tons	603,190 tons	290,581 tons
Pork (retail)	7,590,435 tons	468,076 tons	225,491 tons
Pork (boneless)	7,130,705 tons	439,726 tons	211,834 tons
Turkey (carcass)	2,637,737 tons	162,660 tons	78,360 tons
Turkey (boneless)	2,083,812 tons	128,501 tons	61,904 tons
Fresh / Frozen Seafood	1,818,000 tons	112,110 tons	54,008 tons
Canned Seafood	593,000 tons	36,568 tons	17,616 tons
Cured Seafood	45,000 tons	2,775 tons	1,337 tons
Lamb (carcass)	192,348 tons	11,861 tons	5,714 tons
Lamb (retail)	171,190 tons	10,557 tons	5,086 tons
Lamb (boneless)	126,565 tons	7,805 tons	3,760 tons
Other Chicken (carcass)	136,350 tons	8,408 tons	4,051 tons
Other Chicken (retail)	117,125 tons	7,223 tons	3,479 tons
Other Chicken (boneless)	82,083 tons	5,062 tons	2,438 tons
Veal (carcass)	72,000 tons	4,440 tons	2,139 tons
Veal (retail)	59,760 tons	3,685 tons	1,775 tons
Veal (boneless)	49,320 tons	3,041 tons	1,465 tons
Total (boneless)	30,256,849 tons	1,865,834 tons	898,847 tons

Source: ERS 2009a

Table 3: 2007 U.S. Meat, Poultry and Seafood Availability

	US Production	% Exported	NYS Consumption	NYC Consumption	NYC Per Capita
Chickens	9,000,000,000	16.8%	462,016,303	222,571,891	23.7
Turkeys	271,000,000	9.3%	15,156,986	7,301,732	0.78
Hogs and Lambs	109,000,000	14.2%	5,765,748	2,777,593	0.30
Cattle	34,200,000	5.4%	1,994,969	961,057	0.10
Sheep	2,700,000	4.8%	158,529	76,370	0.01
Total	9,416,900,000	12.32%	509,171,742	245,288,568	26.12

Source: AMI 2009, ERS 2009a

Table 4: 2007 U.S. Slaughtered Food Animal Count

The U.S. Department of Energy (DOE) breaks down total national energy use into four sectors: residential, commercial, industrial and transportation. Residential and commercial users account for 21,640T Btu and 18,540T Btu or 22% and 19%, respectively, of total U.S. energy usage.

The DOE has also conducted surveys of specifically how that energy is used in 2005 residential and 2003 commercial surveys (the most recent available). Survey end use numbers do not sum to total national figures due to considerable losses in generation and delivery, which vary by specific source fuels. 2005 residential end-use survey numbers are presented in figure 5, with interpolated values for NYC based on NYC having 42.9% of the provided NY state values. The 2001 residential survey explored appliance use more fully and found electrical cooking appliances like range tops, ovens and coffee makers consumed around 13.5% of home electrical use outside of water heaters, space heaters and refrigerators.

	U.S.	NY State	NYC	NYC %
Space Heating	4,300T Btu	490T Btu	210T Btu	58.3%
Water Heating	880T Btu	20T Btu	9T Btu	2.4%
Air Conditioning	2,110T Btu	150T Btu	64T Btu	17.9%
Lighting and Electric Appliances	2,260T Btu	100T Btu	43T Btu	11.9%
Refrigerators	510T Btu	30T Btu	13T Btu	3.6%
Gas and Electric Cooking	741T Btu	40T Btu	17T Btu	4.8%
Total	10,550T Btu	840T Btu	360T Btu	100.0%

Source: EIA 2008b, EIA 2009c

Table 5: 2005 Residential Building Energy Consumption

2003 commercial end-use survey numbers are presented in figure 6. Commercial energy end-use is broken down a bit more specifically than residential by type of building and end-use. Values for NYC are interpolated from the figures for the middle Atlantic census division based on NYC having 48% of that division's population.

	All US	NYS / NJ / PA	NYC	NYC %
Space Heating	2,365T Btu	488T Btu	234T Btu	46.4%
Cooling	516T Btu	45T Btu	22T Btu	4.3%
Ventilation	436T Btu	60T Btu	29T Btu	5.7%
Water Heating	501T Btu	74T Btu	36T Btu	7.0%
Lighting	1,340T Btu	184T Btu	88T Btu	17.5%
Office Equipment	69T Btu	11T Btu	5T Btu	1.0%
Computers	156T Btu	25T Btu	12T Btu	2.4%
Other	569T Btu	92T Btu	44T Btu	8.7%
Cooking	190T Btu	31T Btu	15T Btu	2.9%
Refrigeration	381T Btu	42T Btu	20T Btu	4.0%
Total	6,523T Btu	1,052T Btu	505T Btu	100.0%

Source: EIA 2008a

Table 6: 2005 Commercial Building Energy Consumption

Refrigeration and Cooking

Because meats are stored and prepared along with other dietary components, the amount of refrigeration and cooking energy directly associated with meat can only be vaguely estimated. Secondary energy use could also be attributed to additional air conditioning required in home and commercial buildings during large portions of the year to compensate for heat emitted by refrigeration and cooking appliances, although the comparatively cold climate of NYC during much of the year effectively utilizes that energy as space heating. Additional secondary energy usages like lighting, office equipment and amortized restaurant construction energy are not considered because of the philosophical difficulty in attributing quantities of use specifically for meat.

Refrigeration constitutes a very large percentage of American electrical energy use, both at the home and commercial level. The development and deployment of artificial refrigeration machinery in the late 19th century made possible the current centralization and consolidation of the meat processing industry, along with the placement of the geographic and chronological points of slaughter quite a distance from the subsequent points of consumption. Because home refrigeration units used to store meat are also commonly used to store other non-meat foods (like fresh vegetables, dairy, condiments and beverages) and non-food products (like medicines), it is not possible to give an accurate number indicating how much energy is used to refrigerate meat at the home or commercial level. However, assuming that home, retail and wholesale food refrigeration is primarily used for a limited group of items that are commonly stored or served cold, a very rough distribution of refrigeration energy based on mass is provided in figure 7.

	Tons Available	% of Total Mass	US Refrigeration	NYC Refrigeration
Dairy	91.4	27.7%	246.8T Btu	9.1T Btu
Eggs	4.8	1.5%	13.1T Btu	0.5T Btu
Fresh Vegetables	28.1	8.5%	75.7T Btu	2.8T Btu
Frozen Vegetables	5.8	1.8%	15.7T Btu	0.6T Btu
Fresh Fruit	18.0	5.4%	48.5T Btu	1.8T Btu
Cold Beverages	151.7	46.0%	409.4T Btu	15.2T Btu
Meat and Fish	30.3	9.2%	81.7T Btu	3.0T Btu
Total Refrigeration	330.1	100.0%	891.0T Btu	33.0T Btu

Source: Calculated from ERS 2009a, EIA 2008a, EIA 2008b, EIA 2009c

Table 7: 2007 Estimated Energy Use for Residential and Commercial Food Refrigeration

Cooking requires a similarly large amount of energy, but isolating that amount of energy is even more problematic since meats are rarely prepared in total isolation from the other components of a meal. For this analysis, USDA dietary survey data was used to identify the weights of specific groups of foods that generally require cooking at the residential or retail level prior to consumption. Table 8 details the percentages of cooked food weight associated with meat and meat-dominated dishes which are used to calculate an estimate of the percentage of cooking energy used for meat.

	Pounds Per Day Per Person	Lbs Cooked	% of Total Cooked	US Cooking Btu	NYC Cooking Btu
Grain Products	0.67	0.45	20.5%	190.5T Btu	6.6T Btu
Vegetables	0.42	0.36	16.4%	152.4T Btu	5.2T Btu
Fruits	0.37	0.00	0.0%	0.0T Btu	0.0T Btu
Milk and Milk Products	0.60	0.08	3.5%	32.9T Btu	1.1T Btu
Eggs	0.04	0.04	1.8%	16.9T Btu	0.6T Btu
Legumes, Nuts, Seeds, Oils	0.09	0.00	0.0%	0.0T Btu	0.0T Btu
Sugars and Sweets	0.06	0.00	0.0%	0.0T Btu	0.0T Btu
Beverages	2.04	0.86	39.6%	368.8T Btu	12.7T Btu
Meat and Meat Products	0.43	0.40	18.2%	169.8T Btu	5.8T Btu
Total	4.72	2.18	100.0%	931.4T Btu	32.0T Btu

Source: Calculated from FSRG 1997, EIA 2008a, EIA 2008b, EIA 2009c

Table 8: 2007 Estimated Energy Use for Residential and Commercial Cooking

Corporate Energy

Animal products in contemporary American society are almost exclusively produced, processed and distributed by commercial enterprises. Those businesses require management, marketing, investment, regulatory and engineering services, which, in turn, require large staffs of office-based workers. The integration of these workers and their lives into the web of American and global energy usage makes a definition of their exact contribution to energy use for meat-related activities a philosophically and thermodynamically intractable problem.

It can be stated with some certainty that in 2007 the commercial sector used around 18,287 trillion Btu (EIA 2009a) or around 18% of total U.S. energy usage. In 2003, office buildings used around 1,134 trillion Btu, with over 80% of that energy associated with HVAC or lighting (EIA 2008a). Food and fiber accounted for economic activity of around $1.2 trillion in 2004 (Edmondson 2004) out of a gross domestic product of around $11.7 trillion (BEA 2009). In 2006, meat and poultry sales were over $142 billion (AMI 2009).

Using using those numbers as the basis of an assumption that around 10% of U.S. office activity is related to food, 1.2% is directly related to meat and that NYC is around 2.97% of the country's population, table 9 details perhaps 400 billion Btu of energy used in offices around the country might be attributed to support of meat in NYC, not including office activity associated with restaurants, supermarkets and later-stage food processors. 3.5 trillion Btu of office energy might be associated with all food products supplied to NYC. However, a more accurate estimate would require a detailed analysis of the meat industry that is well beyond the scope of this document.

	U.S.	U.S. Food	U.S. Meat	NYC Food	NYC Meat
GDP	$11.7T	$1.2T	$0.142T	$0.036T	$0.00
		10.3%	1.2%		
Commercial Energy	18,540T Btu				
Office Energy	1,134T Btu	116T Btu	13.8T Btu	3.5T Btu	0.409T Btu

Source: Calculated from EIA 2008a, EIA 2009a, Edmondson 2004, BEA 2009, AMI 2009

Table 9: 2007 Estimated Energy Use for Office Activity Associated with Food and Meat

Transportation

Complete statistics are not available for determining the exact sourcing of meat consumed in NYC, therefore it is difficult to estimate the amount of energy required to transport meat to New York City from those unknown source locations. Meat distribution practices are likely controlled more by economic factors than physical distance between source and sink and transportation costs may be only a minor consideration within the larger complexities of business practices and relationships in the meat industry.

Domestic meat transportation is dominated by refrigerated tractor-trailer combinations with the trailers commonly referred to as "reefers" (BTS 2004). The refrigeration units on the fronts of the trailers typically use between a half and three-quarters of a gallon of diesel per hour (depending on weather conditions and load characteristics), with drivers customarily planning on one gallon per hour to provide a margin of safety (TTR 2009). The refrigeration units often also double as warmers when shipping temperature-sensitive loads in cold weather.

While motive fuel usage also varies by climate and terrain, an energy intensity figure of 1,125 Btu per ton-mile is used in this paper for refrigerated trucking, based on 53-foot reefer trucks each

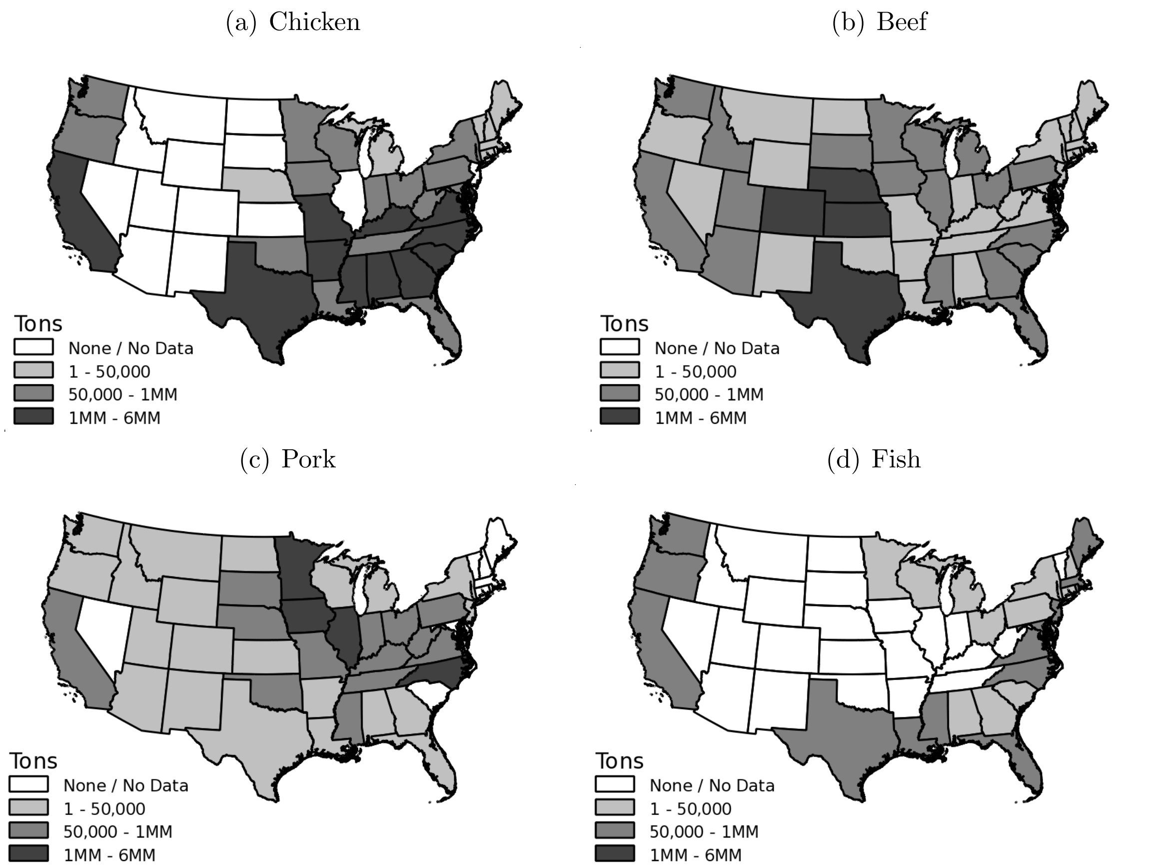

Table 10: U.S. Meat and Fish Production by State

carrying 20 tons of meat, an average tractor-trailer efficiency of 6 miles-per-gallon and 135,000 Btu per gallon of Diesel (TTR 2008). This value is consistent with published national and international averages for truck transport (Corbett 2004, 746; Babcock and Bunch 2007, 242).

These transportation energy estimates are limited to the primary energy of the transportation fuel used. A truly comprehensive life-cycle analysis of any product involving transportation would include energy associated with the construction and maintenance of vehicles, vessels, containers and warehouses supporting the product in question. Energy used for highway construction and maintenance could also be amortized and added to energy totals. However, while these energy values are probably large in absolute terms, when reduced to their share associated with meat in NYC, the values are likely quite small relative to more the more direct (and knowable) energy inputs. Therefore, infrastructure energy expenditures are ignored with the caveat that energy for construction and support of infrastructure will probably be a serious problem as world supplies of fossil fuels dwindle in the coming years.

Sourcing by Market Share

Levay (2009) approached the question of transportation energy by assuming that NYC sourced its meat from states in proportion to each state's percentage of national slaughter volume. Ton-miles are calculated using the distance between each state's centroid and NYC's Hunts Point terminal

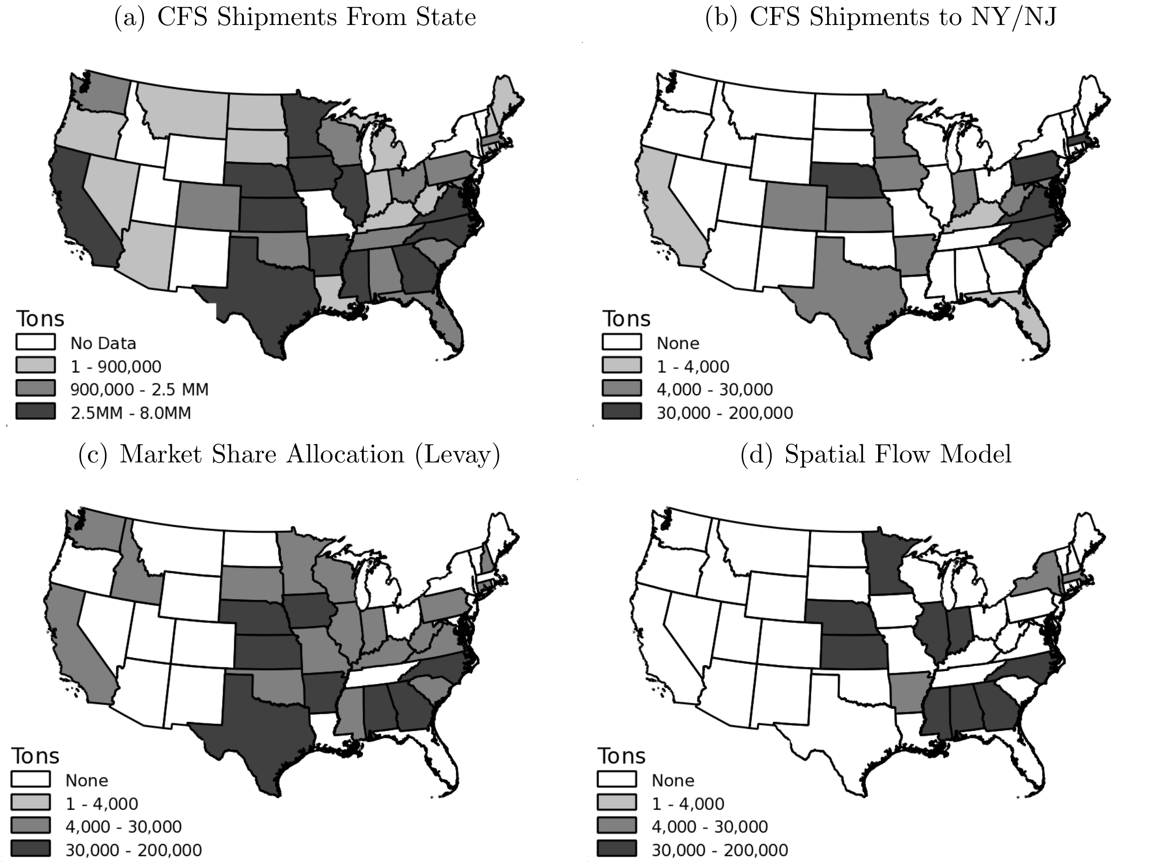

Table 11: Estimates of Meat Source States For NYC

market. Table 12 details an estimate of 0.935T Btu total energy needed to transport NYC's beef, pork and chicken from slaughterhouse to the local distributor using Levay's methodology. Source states are mapped in figure 11.c.

Although Levay's model is straightforward, it makes the debatable assumption that state market share is the primary driver of sales regardless of geography. However, given the geographic concentration of producers of different types of meats in specific regions of the country, the estimate produced by this methodology may be reasonable.

The Commodity Flow Survey

A more robust (but equally problematic) approach to this problem is to use the Bureau of Transportation Statistics' 2002 Commodity Flow Survey (CFS) data, which provides survey-based estimates on flows of general commodity groups between states. Use of this data is complicated by the complexity of commodity shipping patterns as well as significant gaps in the CFS data. Although CFS data separates estimates by commodity group, red meat, poultry and seafood are considered together (two-digit commodity group 05), making it impossible to definitively extrapolate numbers for individual types of meat. The CFS also treats prepared foods separately from fresh and frozen meat, so meat that is incorporated into more complex preparations (like canned soups) can also not be definitively estimated using CFS data.

	% Commercial Slaughter, 2006	NYC Boneless (Tons)	Centroid Distance to Hunts Point (Miles)	Million Ton-Miles	Trillion Btu
Kansas	23%	63,255	1,440	91.1	0.102
Nebraska	21%	59,075	1,520	89.8	0.101
Texas	20%	54,338	1,780	96.7	0.109
Other	8%	23,128	100	2.3	0.003
Colorado	6%	17,834	1,850	33.0	0.037
Wisconsin	5%	12,818	970	12.4	0.014
California	5%	12,818	2,930	37.6	0.042
Idaho	5%	12,818	2,480	31.8	0.036
Illinois	3%	7,802	930	7.3	0.008
Washington	3%	7,802	2,790	21.8	0.024
Pennsylvania	3%	6,966	170	1.2	0.001
Beef Total	100%	278,655		424.9	0.478
Iowa	29%	60,584	1,100	66.6	0.075
Other	16%	33,258	100	3.3	0.004
North Carolina	11%	22,878	520	11.9	0.013
Illinois	9%	19,065	930	17.7	0.020
Minnesota	9%	19,065	1,370	26.1	0.029
Indiana	7%	15,040	690	10.4	0.012
Nebraska	7%	14,617	1,520	22.2	0.025
Oklahoma	5%	9,956	1,490	14.8	0.017
South Dakota	4%	8,897	1,540	13.7	0.015
Virginia	2%	4,237	350	1.5	0.002
Missouri	2%	4,237	1,080	4.6	0.005
Pork Total	100%	211,834		192.9	0.217
Georgia	14%	37,763	944	35.6	0.040
Arkansas	12%	32,715	1,226	40.1	0.045
Alabama	12%	31,745	1,097	34.8	0.039
North Carolina	10%	26,467	520	13.8	0.015
Mississippi	9%	23,627	1,165	27.5	0.031
Texas	7%	18,503	1,780	32.9	0.037
Delaware	4%	11,173	202	2.3	0.003
Missouri	4%	10,504	1,074	11.3	0.013
South Carolina	3%	8,743	730	6.4	0.007
Virginia	4%	9,996	350	3.5	0.004
Other States	21%	54,593	100	5.5	0.006
Chicken Total	100%	265,830		213.68	0.240
Beef, Pork, Chicken Total		756,319		831.49	0.935

Source: Levay 2009, AMI 2009, Google Maps

Table 12: 2007 Estimated Energy Used for Beef, Pork and Chicken Transport Based on Market Share by State

The geographic aggregation of CFS data presents additional challenges. While it is possible to get some statistics for Census Bureau Combined Statistical Areas (CSA), which aggregate Metropolitan Statistical Areas (MSA) roughly corresponding to metropolitan areas, that data has even more gaps than the statewide aggregations. CFS data for New York State lists 265,000 tons of meat / seafood coming from NJ, which seems to indicate that a considerable amount of the meat consumed in New York City comes from distribution centers in New Jersey. These factors make it impossible to directly use CFS statistics for New York State or the NY-NJ-PA-CT CSA to extrapolate NYC statistics.

Given all these issues, figure 13 approaches an estimate of NYC meat and seafood tonnage and ton-miles by combining shipping totals for New York State and New Jersey, then multiplying by the percentage of the combined state's populations (29.7%) that live in the five boroughs of NYC. Where the CFS data does not provide ton-miles, estimates are provided based on the tons of product times the CFS figures for average shipping distance from the source state. Figure 11.b maps estimated meat shipments from states based on total shipments to NYS/NJ.

	NYC		**NYS + NJ**		**Origin State Total**	
Source	(K Tons)	(Est MM Ton-Miles)	(K Tons)	(MM Ton-Miles)	(K Tons)	(MM Ton-Miles)
North Carolina	143.2	73.3	482	284	4,748	2,532
Pennsylvania	71.0	14.1	239	S	2,345	S
Massachusetts	54.9	15.2	185	47	903	513
Nebraska	39.5	51.1	133	172	4,227	2,862
Virginia	35.0	14.1	118	48	2,711	1,029
Delaware	30.9	10.1	104	31	1,037	389
Iowa	19.9	23.1	67	80	4,077	S
Kansas	19.3	29.5	65	98	2,839	2,257
Texas	19.0	31.2	64	105	6,974	3,198
Arkansas	18.4	22.1	62	75	4,669	2,756
South Carolina	14.3	10.5	48	35	1,364	604
Maryland	10.1	2.1	34	7	1,120	303
West Virginia	9.8	3.5	33	11	238	115
Minnesota	7.4	9.0	25	32	3,397	2,015
Colorado	7.1	12.3	24	41	1,415	1,395
Indiana	5.9	4.1	20	13	871	285
Florida	3.9	4.5	13	15	1,971	687
California	3.6	10.3	12	34	7,389	2,430
Kentucky	3.3	2.6	11	8	743	220
CFS Total	516.5	342.7	1,739	1136	84,506	41,352

Source: BTS 2004
S - Estimate does not meet publication standards because of high sampling variability or poor response quality.

Table 13: Estimate from 2002 Commodity Flow Survey of Meat and Seafood Shipped to NYC

The total computed flow from the CFS of 517,000 tons is only 58% of the availability estimate of 899,000 tons. This is likely due to missing data from key production states, notably Georgia, Alabama, and Mississippi, as well as NY State itself. Additional lost product may be associated with meat shipped into the city as prepared products. There is also additional shipping weight above the availability estimate that should be expected for packaging associated with meat shipments. Figure 11.a shows states by their total meat / seafood shipping tonnage (regardless of destination), which gives some hint as to where the missing meat may be coming from.

Table 14 gives a total meat and seafood transportation value of 0.681T Btu by performing a simple linear extrapolation from the CFS values to the larger NYC meat availability estimate. This gives a smaller overall value than the Levay methodology despite the inclusion of seafood and may underestimate increased flows from more distant states (such as seafood from Alaska).

	Tons	MM Ton-Miles	Avg Miles / Ton	Reefer Truck T Btu
CFS Extrapolation to NYC	516,483	347.84	673.49	0.391
“Missing” Meat	382,364	257.52	673.49	0.290
Total Meat / Fish Availability	898,847	605.36		0.681

Source: BTS 2004

Table 14: Extrapolation from 2002 Commodity Flow Survey for NYC Meat and Seafood Shipping Transport Energy

Iterative Spatial Flow Model

In a final attempt to estimate origin state share and associated transportation energy, an iterative spatial flow model was created based on total state production statistics and each state’s share of that production based on state population in the 2000 census. Beef, pork, young chicken and landed fish (ocean and freshwater) were considered separately. After each state satisfied its own consumption share, product was incrementally exported from each state with a surplus to the nearest states with unmet needs. This gives a more limited list of states than the Levay or CFS values, reflecting both market dominance of specific states and weighting positively for geographic proximity to NYC. Table 15 details the estimated 1.169T Btu needed to transport red meat, poultry and seafood to NYC. Source states are mapped in figure 11.d.

Although some fresh Alaskan seafood is transported by air, most Alaskan seafood is frozen, shipped to the lower 48 states by barge and then delivered by truck (ASMI 2005), so the Btu rate for trucking from Anchorage is used for simplicity. When that substantial transportation cost for Alaskan seafood is not considered, the aggregate NYC meat energy use value is surprisingly close to the Levay estimate.

Source	Chicken	Beef	Pork	Seafood	Centroid Miles to Hunts Point	MM Ton-Miles	Reefer Truck T Btu	Btu / lb
NC	95,887				520	49.9	0.056	293
KS		184,103			1,440	265.1	0.298	810
GA	50,098				944	47.3	0.053	531
NE		91,731			1,520	139.4	0.157	855
AL	44,173				1,097	48.5	0.055	617
MS	44,173				520	23.0	0.026	293
IL			88,080		930	81.9	0.092	523
MN			86,305		1,365	117.8	0.133	768
AR	28,012				1,226	34.3	0.039	690
AK				45,653	4,400	200.9	0.226	2,475
IN			36,870		690	25.4	0.029	388
MA				21,055	205	4.3	0.005	115
NY	5,926	2,821	578	6,253	100	1.6	0.002	56
Total	268,268	278,655	211,834	72,961		1,039.4	1.169	703

Note: Model population and agricultural statistics from NASS 2008, NASS 2009a, NASS 2009b, NOAA 2009a, USCB 2008

Table 15: Spatial Model Estimate of NYC Meat and Seafood Sourcing and Transport Energy

Imported Red Meat

In 2007 the United States imported around 1.4 million tons of red meat, around 9% of total availability (ERS 2009a). While this may seem like an extravagant use of energy, ocean transport is 3 to 4 times more efficient than truck transport, and sourcing food overseas can in some cases be more energy efficient (in transportation energy) than domestically sourced foods. For example, beef shipped 1,400 miles by truck from Kansas (at 800 Btu / lb) may be as much as twice as energy intensive (in terms of vehicle fuel energy per pound of meat) than meat shipped 2,000 miles from Costa Rica or Denmark (around 400 Btu / lb). While there are complex ecological, political, health and moral issues involved with imported food, these numbers demonstrate how the concept of "food-miles" can be deceptive.

NYC's share of that overseas meat trade (not including seafood) is around 43,000 tons and table 16 details an estimated 0.088T Btu of energy used to transport that transportation energy usage.

The complexities of the global seafood industry make it very difficult to assess sourcing, so seafood is not included in these numbers. While 72% of Canada's beef is grown in Alberta, 17% is raised in Ontario (which shares a border with New York State) and, therefore, Canadian beef imports are assumed to travel by truck (CCABIC 2001). Mexican imports are also assumed to travel by truck (at a considerable energy premium over water shipping), although Mexico's size and location might favor shipment of more exports via water and/or to the west coast rather than the east coast.

Refrigerated ships used for meat typically hold between 100 and 300 40-foot containers, each (as with refrigerated trucks) containing around 20 tons of product. Refrigerated ships typically travel at 18 - 23 knots (a bit faster than other containerized ships) and use IFO-180 or IFO-380 bunker fuel (Kohli 2000). Ocean shipping energy intensity figures provided by Corbett (2004) vary from between 140 and 550 Btu per ton-mile with a container ships modeled at using between 277 and 415 Btu per ton-mile. Assuming additional energy load to generate electricity to power the refrigeration units during the journey, a high-end figure of 400 Btu per ton-mile is used for calculations in this paper.

	US Beef (tons)	US Pork (tons)	US Sheep (tons)	US Total (tons)	NYC (tons)	NYC (miles)	NYC T Btu	Btu / lb
Canada	264,076	278,759		542,835	16,126	476	0.0086	268
Australia	296,919		50,067	346,986	10,308	9,823	0.0405	1,965
New Zealand	169,813		16,323	186,136	5,530	8,509	0.0188	1,702
Uruguay	118,822			118,822	3,530	5,737	0.0081	1,147
Brazil	93,934			93,934	2,791	4,489	0.0050	898
Denmark		36,039		36,039	1,071	3467	0.0015	693
Mexico	16,654	15,595		32,249	958	2000	0.0022	1,125
Nicaragua	29,555			29,555	878	1782	0.0006	356
Argentina	23,169			23,169	688	5062	0.0014	1,012
Poland		10,215		10,215	303	3707	0.0004	741
Costa Rica	6,004			6,004	178	2026	0.0001	405
Italy		3,948		3,948	117	4199	0.0002	840
Honduras	153			153	5	1689	0.0000	338
Other countries	1,850	8,440	281	10,571	314			
Total	1,020,949	352,996	66,671	1,440,615	42,797		0.0875	
	70.9%	24.5%	4.6%					

Source: ERS 2009, PortWorld, Corbett 2004
Note: Canada truck mileage from Guelph, OT, Mexico truck mileage from Matamoros.
Ports: Wilmington, Brisbane, Auckland, Montevideo, Vitoria, Paranagua, Puerto Cabezas, Copenhagen, Gdansk, Puerto Limon, Naples, La Ceiba.

Table 16: 2007 U.S. Red Meat Imports

Imported Seafood

According to the National Oceanic and Atmospheric Administration (NOAA), the U.S. imported around 2.7 million tons of seafood in 2007, with shrimp having the largest share at 22%. The U.S. also exported around 1.4 tons of seafood (NOAA 2009b). While NOAA keeps fairly detailed statistics on seafood imports and exports, the large number of countries and different species makes it impossible to determine exact transportation modes or ton-miles. It is likely that some fresh seafood is imported via airplane, but in the absence of detailed data for this analysis, most seafood is assumed to be imported frozen via ship.

Table 17 details transportation energy expenditures for seafood. Over 80% of Canadian landings are from the east coast fisheries (FOC 2009), so shipping from Canada is assumed to be via truck from Halifax. Veracruz was chosen as the Mexican port since it is in Mexico's largest tilapia producing state (Fitzsimmons 2000), but it is likely that some significant portion of Mexican seafood is shipped via truck and airplane. Because the less-dominant "other" countries are widely distributed around the globe, a median shipping distance of 8,000 miles was chosen. Shipping energy intensities are the same as given above for red meat.

	2007 U.S. Imports	Share	NYC	Miles	T Btu	Btu / lb
China	594,304 tons	21.5%	17,655 tons	11,485	0.081	2,297
Thailand	384,791 tons	13.9%	11,431 tons	10,976	0.050	2,195
Canada	378,038 tons	13.7%	11,230 tons	892	0.011	502
Chile	164,891 tons	6.0%	4,898 tons	4,856	0.010	971
Indonesia	137,797 tons	5.0%	4,094 tons	10,433	0.017	2,087
Ecuador	120,099 tons	4.3%	3,568 tons	2,617	0.004	523
Vietnam	104,453 tons	3.8%	3,103 tons	11,000	0.014	2,200
Mexico	101,411 tons	3.7%	3,013 tons	1,939	0.002	388
Philippines	75,339 tons	2.7%	2,238 tons	11,347	0.010	2,269
Taiwan	49,891 tons	1.8%	1,482 tons	10,994	0.007	2,199
Other	650,251 tons	23.5%	19,317 tons	8,000	0.062	1,600
Total	2,761,265 tons	100.0%	82,030 tons		0.267	1,630

Source: Calculated from PortWorld 2009 and NMFS 2009.
Ports: New York, Zhanjiang, Bangkok, San Vincente, Jakarta,Manta, Ho Chi Minh City, Veracruz, Manila, Kaohsiung.

Table 17: 2007 U.S. Seafood Imports

Final Delivery

Although the number of final travel miles of meat from the wholesaler to plate are fairly small, the vagaries of logistics in the densely-settled five boroughs dictate use of indirect routes and smaller delivery vehicles that give the time and distance characteristics of these final miles an energy premium over long-distance truck, rail and ship.

To estimate energy used in delivering meat from the terminal market (assumed to be Hunts Point for this analysis) to restaurants and retail businesses, 50 of the 20,000 restaurants in New York City were chosen at random from a list downloaded from the NYC Department of Health website. Restaurants were chosen as proxies for all delivery destinations because of their wide distribution and assumed geographic proximity to retail meat and/or grocery points. Mileage and travel time from the Hunts Point Terminal Market were obtained via Google Maps and averaged to create citywide average round trip of 27 miles and one-way travel time of 27 minutes at an average speed of 30 MPH.

Meat is delivered to stores and restaurants via a wide range of vehicles - from small class 2 vans (three ton gross vehicle weight) to full-sized class 8 tractor-trailers. As an worst-case scenario, a three-ton refrigerated delivery van delivering a ton of meat and averaging 10 MPG over a 27-mile round trip would use 2.7 gallons. At 115,000 Btu per gallon of gasoline, that works out to 11,500 Btu per ton-mile - over ten times the 1,125 Btu per ton-mile required for long-haul trucking. Idling and traffic congestion likely add additional fuel use, with idling responsible in some situations for as much as a 20% of fuel use. (Gaines, Vyas and Anderson 2006). However, table 18 shows that because of the limited amount of mileage associated with final product delivery, the overall energy use is fairly small within the context of energy used in prior phases.

	Avg Miles	Avg Minutes	Average MPH	% of Restaurants	Tons Meat	Van T Btu
Bronx	5.9	16.0	22.1	10%	94,208	0.0011
Brooklyn	18.9	34.4	32.9	25%	220,620	0.0025
Manhattan	10.9	23.8	27.5	39%	346,142	0.0040
Queens	12.7	25.0	30.4	23%	202,472	0.0023
Staten Island	29.2	49.0	35.8	4%	35,406	0.0004
NYC	13.49	26.9	30.1	100%	898,847	0.0103

Source: NYCDOH 2009, EIA 2009a

Table 18: Energy for Final Delivery of Meat in NYC

Processing

Ramirez, Patel and Blok (2006) studied meat processing in France, Germany, the Netherlands and the United Kingdom in the 1980s and 1990s to determine the amount of energy used in livestock slaughter. While the numbers varied considerably by country and over time, generalized figures are presented in table 19 and applied to U.S. and NYC meat availability statistics. Numbers also vary based on the amount of processing performed. Frozen, deboned and packaged meat requires nearly twice as much energy to process as chilled whole meat. Since almost all meat receives additional processing at some point between slaughter and cooking, the more liberal figures are used for all meats.

	Btu per Ton	US Tons	NYC Tons	US Btu	NYC Btu
Beef	3,576,657	9,380,047	278,655	33.5T Btu	1.00T Btu
Veal	3,597,542	49,320	1,465	0.2T Btu	0.01T Btu
Lamb	3,597,542	126,565	3,760	0.5T Btu	0.01T Btu
Pork	4,216,716	7,130,705	211,834	30.1T Btu	0.89T Btu
Turkey	6,828,695	2,083,812	61,904	14.2T Btu	0.42T Btu
Young Chicken (broilers)	8,961,244	8,948,317	265,830	80.2T Btu	2.38T Btu
Other Chicken	8,961,244	82,083	2,438	0.7T Btu	0.02T Btu
Total Processing		27,800,849	825,887	159.4T Btu	4.74T Btu

Source: Ramirez, Patel and Blok 2006

Table 19: Energy used for Slaughter and Processing in the U.S. and NYC

Ramirez, Patel and Blok provide a breakdown of the components of processing associated with this energy use, primarily based on the work of Dutch researchers. However, the balance of use between electricity (primarily for cooling) and direct fuel (primarily for heating) varied among the studied countries. Perhaps most notable is France's reliance on higher ratios of electricity use over, presumably because of the dominance of electricity from nuclear plants in their energy mix.

	Electricity		Direct Fuel	
Hog Slaughter	Cooling	49-70%	Gas oven	60-65%
	Slaughter	5-30%	Cleaning and disinfecting	18-20%
	Water cleaning	5-7%	Singeing	15%
	Lighting	2-8%	Space heating	7%
	Evisceration	3%		
Cattle Slaughter	Slaughter	26%	Cleaning and disinfecting	80-90%
	Evisceration	3%	Space heating	10-20%
	Cooling	45-70%		
	Compressed air, lighting, machines	30%		
Poultry Slaughter	Cooling	52-60%	Singeing	60%
	Machines and compressed air	30%	Cleaning and disinfecting	30%
	Lighting and ventilation	4%	Space heating	10%
Meat Processing	Cutting and mixing	40%	Cleaning and disinfecting	25%
	Cooling	40%	Space heating	15%
	Packing	10%		
	Lighting	10%		

Source: Ramirez, Patel and Blok 2006

Table 20: Breakdown of Energy used for Slaughter and Processing

A more comprehensive life-cycle analysis of energy use for meat could also include energy used to manufacture, recycle and dispose of packaging as well as the energy used to treat and deliver the water used in processing and the waste water created by processing. However, the indirection and complexity of such an analysis is left for later researchers.

Seafood processing is addressed in the following section on production.

Production

Generalized analysis of fossil-fuel inputs needed for production of specific animal-based food products is hampered by the complex interdependencies in contemporary animal production techniques and the corresponding philosophical questions of which inputs (such as amortization of energy used in production of farm machinery) should be considered in the final tallies. The agriculture and energy industries are well-monitored and agricultural science is a very vibrant and active field, but combining information from those different fields to develop overall energy statistics is an inexact art fraught with caveats.

Baseline Pimentel Ratios

The simplest approach is to use the ratios of fossil-fuel inputs to protein calorie outputs provided by David Pimentel (2007), an agricultural sciences professor at Cornell University who has done extensive work on food energy research since the 1970s. His conclusions have often been regarded as pessimistic since the early days of his career (Gordon and Pryor 1976) and he includes items (like amortization of energy used to make farm machinery) that others neglect. Pimentel also has a tendency to use old data that gives debatable estimates when applied to more efficient contemporary agricultural practices (Wang 2005). However, he is a widely-published and widely-cited author and his analysis certainly has some comparative value at an individual product level even if the numbers may be debatable when aggregated into comprehensive totals.

Table 21 uses Pimentel's fossil-fuel-to-protein ratios along with averaged proportions of protein calories per unit of meat, an assumption of 4 calories per gram of protein (MHS 2008), and earlier estimates of NYC meat consumption to come up with overall Btu values for NYC meat consumption. His figures for eggs, milk and grass-fed beef are presented for comparison but are not included in the energy total.

Pimentel's ratios are "black boxes" in that they do not detail methodology or the specific inputs included. While they are used as the values for totals in this paper, they are probably best seen simply as a baseline for comparison with other models rather than definitive values for making critical public policy decisions.

	Fossil Btu / kcal Protein	kcal Protein / lb Product	Fossil Btu / lb Product	US Tons Available	US Production	NYC tons Product	NYC Production
Lamb	226	399	90,228	126,565	23T Btu	3,760	0.7T Btu
Beef (grain fed)	159	337	53,532	9,380,047	1,004T Btu	278,655	29.8T Btu
Eggs	155	210	32,551				
Beef (range fed)	79	337	26,766				
Pork	56	243	13,498	7,130,705	193T Btu	211,834	5.7T Btu
Milk	56	62	3,425				
Turkey	40	223	8,850	2,083,812	37T Btu	61,904	1.1T Btu
Young Chicken (broilers)	16	432	6,850	8,948,317	123T Btu	265,830	3.6T Btu
Total				27,669,446	1,379T Btu	821,983	41.0T Btu

Source: Derived from Pimentel and Pimentel 2008

Table 21: 2007 Estimated Energy Use for Meat Production

Feed and Forage

All commercially-grown animals are fed some form of harvested food during part or all of their lifetimes, and energy costs associated with growing, harvesting and processing these crops constitute the dominant energy inputs for contemporary meat production (Pelletier 2008, Pimentel et al 1980).

Unlike their analysis for livestock production, Pimentel et al (2007) have published a more details about the specific areas of energy use in the production of the three major forage crops (table 22) and the two major grain feed crops. Actual application of these per pound numbers is specific to the feed demands of different animals, which are discussed later.

Cattle

Most beef calves are born born on and live at least the first few months of their lives on open pastures in "cow-calf" operations. Although calves can be born at any time of the year, ranchers commonly limit a bull's run with the cows to 45- to 60-day period in the summer so that calves are born in the following spring after a nine-month gestation period (Anderson 2009). Cows are usually bred within three months of giving birth (while they are still nursing) so that they can

	Corn	Soy	Alfalfa	Tame Hay	Corn Silage
Machinery	1,633,736 Btu	577,745 Btu	577,745 Btu	577,745 Btu	1,155,491 Btu
Diesel	1,609,663 Btu	709,343 Btu		584,043 Btu	2,014,951 Btu
Gasoline	649,964 Btu	433,309 Btu	2,092,820 Btu		1,719,682 Btu
LP Gas		40,121 Btu			
Nitrogen	3,928,669 Btu	94,686 Btu	166,744 Btu	165,139 Btu	2,736,588 Btu
Phosphorus	433,309 Btu	250,356 Btu	216,655 Btu	38,516 Btu	317,760 Btu
Potassium	402,817 Btu	77,033 Btu	151,498 Btu	41,084 Btu	192,582 Btu
Limestone	505,527 Btu	988,587 Btu	90,489 Btu	7,583 Btu	283,095 Btu
Seed	834,521 Btu	889,086 Btu	447,753 Btu	1,011,055 Btu	762,303 Btu
Irrigation	513,551 Btu				
Insecticides	449,358 Btu		55,791 Btu		340,669 Btu
Herbicides	995,006 Btu	208,630 Btu	32,068 Btu	160,340 Btu	400,851 Btu
Electricity	54,565 Btu	46,541 Btu	119,462 Btu	120,364 Btu	55,136 Btu
Transportation	271,219 Btu	64,194 Btu	54,443 Btu	36,311 Btu	87,026 Btu
Btu per acre	12,281,905 Btu	4,379,631 Btu	4,015,169 Btu	2,754,104 Btu	10,085,352 Btu
Yield per acre	7,722 lbs	2,380 lbs	6,095 lbs	4,461 lbs	27,675 lbs
Btu per pound	1,591 Btu / lb	1,840 Btu / lb	659 Btu / lb	617 Btu / lb	364 Btu / lb

Source: Pimentel and Pimentel 2008

Table 22: Energy Use for Feed and Forage Crop Production

produce one calf a year for five to seven years before they themselves are sent to market for slaughter (Webster 1992).

Cattle have three distinct phases of feeding. Calves nurse until they are weaned at six to nine months of age and between 450 and 600 pounds. Male calves (steers) and female calves (heifers) can then be auctioned to "backgrounding" facilities or backgrounded on the farm where they were born until they are 700 to 750 pounds. During backgrounding, the calves are pastured or fed hay or silage. In the final phase starting at 12 to 18 months of age, the steers and heifers not kept as replacements for the breeding process are sent to feedlots. At the feedlots, the cattle are "finished" on a primarily grain diet for four to six months until they reach a slaughter weight of 1,100 to 1,250 pounds at an age of 18 to 22 months. (Neel 1998, NCBA 2009, UBC 2009, ERS 2008)

While there are a wide variety of factors that can affect the time in each phase, table 23 gives feed energy consumption example based on medians of the figures above for a hypothetical calf conceived in August and born in April. The mother is assumed to be fed hay for six months of the nine-month gestation as well as two months of nursing (Gill 1999). The calf is then backgrounded for six months on primarily corn silage at around 35 pounds per day (Dupchak 1999). Finally, the cow is finished on a feedlot for six months of primarily corn-based rations at an average rate of 6 pounds feed for each pound of weight gain (ERS 2008). Additional costs for the bull, unproductive cows, unsuccessful pregnancies or feed additives are not considered.

Phase	Months (Fed)	Weight	Feed Type	Feed Weight	Feed Energy
Gestation	9 (6)	-	Pasture + Forage (Mother)	5,400 lbs	3,300,000 Btu
Nursing	8 (2)	75 - 450 lbs	Pasture + Forage (Mother)	1,800 lbs	1,200,000 Btu
Backgrounding	6 (6)	450 - 750 lbs	Silage + Hay	6,300 lbs	2,300,000 Btu
Feedlot	6 (6)	750 - 1,200 lbs	Grain-based	2,700 lbs	4,300,000 Btu
Feed Total				16,200 lbs	11,100,000 Btu
Btu per pound (boneless)		492 lbs			22,560 Btu

Source: Calculated from Neel 1998, NCBA 2009, UBC 2009, ERS 2008, Pimentel and Pimentel 2008.

Table 23: Feed Energy Use for a Hypothetical Beef Steer

The hypothetical steer feed energy estimate of around 22,500 Btu per pound of beef (assuming 492 pounds of boneless meat per steer) is within the 26,000-46,000 Btu, range presented by Ward, Knox and Hobson (1977). However, the estimate (which is largely based on Pimentel's feed crop energy use models) is only around half of the value calculated from Pimentel's energy-per-pound ratios. Significant amounts of additional energy could be considered for transportation, facilities operation, losses to illness, and amortization of energy used for infrastructure and equipment manufacture. However, the extent of the differential demonstrates the generosity of Pimentel's overall numbers.

Swine

The biological cycle of hogs is considerably faster than that of cattle, and since most commercially-produced hogs in America spend their entire lives in confined animal feeding operations (CAFOs), the process of raising hogs is somewhat more controlled and predictable than that of raising cattle.

A 450-pound sow produces around 2 litters per year and is generally replaced after four litters (Lawrence and Ellis 2008). Litter size averages nine piglets following a 16-week gestation period. The litter is nursed for an additional two to three weeks and the sow can be mated again shortly after the litter is weaned at an average individual weight of 10-20 pounds. "Weaner" pigs are backgrounded for six weeks until they reach a weight of 20-60 pounds. Finally, the "feeder" pigs are finished on an intense diet for four to five months until they reach a slaughter weight of 240-270 pounds at an age of 22-26 weeks from birth. Actual times vary by breed, climate and feeding conditions, and the gestation/weaning, backgrounding and/or finishing phases are sometimes performed in separate facilities (ERS 2009c).

The feed efficiency of pigs varies widely by age, feed composition, and environmental conditions. Typical weaner pig feed efficiency is around 1.5 pounds feed for each pound of weight gain to 55 pounds, while feeder pigs can vary from 2.5 to 5.0 (Reese et al 1985, Goodband 2009). Feed energy consumption is detailed in table 24 for a hypothetical hog weaned at 20 pounds, finished at 50 pounds and slaughtered at 270 pounds. Feed amounts are from Carr (1998) and Lawrence and Ellis (2008) and assume a feed efficiency of 1.5 for weaners and 3.0 for feeders.

	Days	Weight	Feed	Corn	Soy	Feed Energy
Gestation	112		543 lbs	86%	12%	860,000 Btu
Nursing (Lactation)	20	3-20 lbs	229 lbs	75%	16%	340,000 Btu
Backgrounding	42	20-50 lbs	45 lbs	42%	56%	80,000 Btu
Finishing	123	50-270 lbs	660 lbs	74%	23%	1,060,000 Btu
Total	297	270 lbs	1,477 lbs			2,340,000 Btu
Boneless Meat		120 lbs				19,500 Btu/lb
U.S. Availability		7,130,705 tons				123.4T Btu
NYC Total		211,834 tons				3.7T Btu

Source: Calculated from Carr 1998, Lawrence and Ellis 2008, Pimentel and Pimentel 2008.

Table 24: Feed Energy Use for a Hypothetical Iowa Hog

The estimate of around 19,500 Btu/lb is considerably above Pimentel's 13,500 Btu/lb and does not include additional direct and indirect fossil fuel energy expended during the production process.

While no attempt is made to detail these additional energy amounts in this paper, table 25 gives Lawrence and Ellis' average dollar amounts for Iowa in 2008, which may give some indication of their significance.

	Cost Per Hog
Buildings and equipment	\$14.21
Labor	\$11.40
Feed	\$6.55
Medicines and Veterinary	\$4.72
Utilities	\$2.54
Manure handling	\$1.90
Transportation	\$1.68

Source: Lawrence and Ellis 2008.

Table 25: 2008 Estimated Costs per Finished Hog in Iowa

Poultry

The most common poultry animals are young chickens referred to as "broilers" who grow quickly and have high levels of feed to growth weight efficiency. Breeder hens are placed in breeder houses at 20 weeks of age and usually begin laying eggs by 24 weeks. The laying cycle lasts around 40 weeks and while it is possible to get a second (less productive) laying cycle out of hens, breeder hens are commonly sold for slaughter after a single laying cycle that produces around 140 chicks. Eggs are transferred to a hatchery for the 21-day incubation period. Newly-hatched chicks are transferred to a grow-out facility where they are raised to a slaughter weight of 3.5 to 5.0 pounds in around 60 days. A typical five pound broiler requires 15 pounds of feed and yields 3.75 pounds after dressing. (IRS 2002, EPA 2007, VS 2009, Hamre 2008)

Turkeys are raised with procedures similar to chickens, although the times and weights are greater. Breeder hens begin laying around 30 weeks of age for around 24 weeks and produce around 70 eggs per hen. Unlike chickens, the breeder hens are not substantially heavier than their progeny and are processed as regular meat. Non-breeders are raised for a total of 15 to 25 weeks with males requiring longer than females. Male turkeys at 20 weeks are commonly 35-40 pounds. Turkeys are sometimes raised in two or three different facilities to accommodate specific needs at different phases of growth (NASS 2007, EPA 2007).

Poultry feed is a bit more complex than rations for cattle or swine. While the majority of the feed is commonly corn and soy, formulations also include significant amounts of fish meal, poultry by-products, salt and limestone. With 15 pounds of a generic 70% corn and 20% soy diet yielding 3.75 pounds of meat, the yield is 5,900 Btu fossil fuel energy per pound of broiler chicken, which is consistent with Pimentel's figure of 6,850 Btu per pound. Note that the 5,900 Btu value does not include additional energy inputs to the production process such as heating, ventilation, transportation, non-grain feed products or amortized building/equipment construction/maintenance.

Pelletier (2008) performed a more comprehensive life-cycle analysis of poultry which comes up with a 6,400 Btu per pound value, of which 89% is devoted to feed. Pelletier's total does not include amortization of building/equipment costs, but does include poultry litter (waste) as a negative cost because litter can be used as fertilizer that offsets the energy expenditure needed to manufacture synthetic fertilizers. Table 26 details Pelletier's numbers and extrapolates them to the U.S. and NYC.

	Btu / Lb	U.S.	NYC
Meat	1 lb	8,948,317 tons	265,830 tons
Feed	5,700	102.01T Btu	3.03T Btu
Hatchery chicks	200	3.58T Btu	0.11T Btu
On-farm inputs	1,300	23.27T Btu	0.69T Btu
Litter management	(700)	(12.53T) Btu	(0.37T) Btu
Total	6,400	114.54T Btu	3.40T Btu

Source: Calculated from Pelletier 2008.

Table 26: Estimated Fossil Fuel Energy for Chicken

Seafood

Production and processing numbers for seafood are very slippery target due to the wide variety of species harvested and/or grown over a broad geographic area. The prominence of factory fishing vessels, which both capture and process fish, add additional complexity. Table 27 details some fairly old energy intensity values cited by Pimentel (2007) for ocean vessels as well as numbers for some common aquaculture species. Labor-intensive longline capture of wild fish is a remarkably fuel-efficient production process while shrimp farming has an energy intensity comparable to grain-fed beef.

	Btu / lb	US Range	NYC Range
Norwegian Net and Longline (1982)	1,200	5.89T Btu	0.18T Btu
Continental Shelf Longline (1982)	2,300	11.30T Btu	0.34T Btu
U.S. Factory Vessel (1982)	4,800	23.58T Btu	0.70T Btu
Louisiana Farmed Catfish (1974)	33,900	166.52T Btu	4.95T Btu
Thai Farmed Sea Bass (1990)	38,500	189.11T Btu	5.62T Btu
Thai Farmed Shrimp (1992)	58,600	287.84T Btu	8.55T Btu

Source: Calculated from Pimentel 2007.

Table 27: Estimated Fossil Fuel Energy for Seafood Production

With the extreme complexity of production sourcing data, as well as the age, uncertainty and wide range of production energy intensity estimates, it is not possible to give a reliable estimate of fossil-fuel energy used for the production and processing energy of seafood. Given the estimated 73 million tons of seafood consumed in NYC, the possibilities range from 0.18T Btu (using the Norwegian longline energy intensity) to 8.55T Btu (using the Thai shrimp farming intensity). For this analysis, medians of 147T Btu and 4.4T Btu are used for the U.S. and NYC, respectively, with the caveat that the actual value might be higher or considerably lower. Regardless, environmental degradation, species loss and depletion of ocean fisheries are probably more serious concerns for the future than energy used to catch the fish.

Grass-Fed Beef As An Alternative

Given the complete dependence of contemporary confined animal feeding operations on fossil fuel and health concerns with the products of such operations, the idea of returning to grass-fed beef has risen to prominence in recent years ("The Grass-Fed Revolution"). Pimentel (1980) explored the practicality of moving exclusively to grass-fed beef, but such a move would likely result in significantly reduced amounts of available meat.

In 1980 the population was around 228 million people and annual livestock production produced around six million tons of protein from around 27 million tons of red meat and poultry. Pimentel's estimate was that it would be possible to produce 3.2 million tons of protein on the 380 million HA of pasture and forest range that were then in use for livestock grazing.

Using Pimentel's conversion ratios of meat to protein, the 30.3 boneless tons of animal product produced in the US (through pasture and CAFOs) in 2007 works out to 5.1 million tons of boneless meat. However, 2007 pastureland was only around 192 million HA or about half of what it was in 1980. If the same protein yield of 16.8 lbs protein per HA per year applies, that means only around 1.5 million tons of protein (28% of current US availability) could be produced with just ruminants (cows and sheep) on currently active grazing land. And, as is described above, growing and harvesting of forage to get the animals through the winter would still require significant amounts of energy for harvesting equipment.

Presumably, more land would be made available for grazing and some grain-fed poultry might be kept around to make up some of the difference. But if Pimentel's figures are true, it does not seem reasonable to think it would be possible to switch to exclusively grass-fed beef and maintain anything close to the currently high levels of animal protein consumption in America

Alternative Methodology

Eshel and Martin (2006) took a top-down approach to calculating meat energy by using Heller and Keoleian's (2000) estimate of total energy used for food, then isolating the portion used for meat by using the ratio of calories from meat to total dietary calories based on per capita numbers supplied by the the Food and Agriculture Organization of the United Nations (FAOSTAT 2005). Their numbers are summarized in table 28 and extrapolated to New York City.

	Per Capita Diet	U.S. Energy	NYC share
1999 Total		96,800T Btu	2,876T Btu
Food Energy	3,774 kcal	10,200T Btu	303T Btu
Animal-based Food Energy	1,045 kcal	2,825T Btu	84T Btu
Meat Energy	565 kcal	1,526T Btu	45T Btu

Source: Derived from Eshel and Martin 2006

Table 28: Energy For Meat Derived From Share of Food Energy

The model comes in somewhat below the values calculated in this paper (82% of the U.S. estimate and 77% of the NYC estimate) and this may be attributable to a couple of significant factors. First, comprehensive national models of food energy use are highly debatable and Pimentel's

(2007) estimate of 16% of total energy use is significantly above Heller and Keolein's estimate of 10.2%. Second, since meat production is essentially the inefficient conversion of feed plant protein to animal protein, meat production is inherently more energy intensive than plain commodity production and the proportion of food energy associated with meat may therefore be somewhat higher than the simple caloric ratio to overall diet.

Concluding Thoughts

From the perspective of overall fossil fuel energy use, meat represents a comparatively small share. However, this paper also demonstrates that fossil fuel energy is an integral part of contemporary agricultural techniques and that those techniques will probably have to change as cheap, abundant fossil fuels are replaced by more-expensive and complex renewables. And aside from energy considerations, issues with environmental degradation, population growth and climate change certainly give reason to believe that current meat production techniques are not infinitely sustainable or scalable. That may not be a bad thing from a moral, culinary or public health perspective, but it is food for thought nonetheless.

So, perhaps the lesson from all this is that we should appreciate our inexpensive Whoppers and Big Macs and savor them more consciously than we have in the past. They may well become an expensive delicacy in the not too distant future.

Acknowledgments

The author gratefully acknowledges the contribution of Michael Levay for his initial research on this topic as well the invaluable assistance of Peter Marcotullio in the preparation of this paper.

Bibliography

Alaska Seafood Marketing Institute (ASMI). 2005. Handle With Care: The Alaska Shipper's Guide To Seafood Quality.
http://www.alaskaseafood.org/industry/qc/pages/pub-hwcs.html
(last accessed 24 July 2009).

American Meat Institute (AMI). 2009. The United States meat industry at a glance.
http://www.meatami.com/ht/d/sp/i/47465/pid/47465
(last accessed 16 July 2009).

Anderson, Les. 2009. Getting Cows Bred in July and August. Ohio Beef Cattle Letter, July 1.
http://beef.osu.edu/beef/beefJuly1.html
(last accessed 27 July 2009).

Babcock, Michael W. and James L. Bunch. 2007. Energy Use and Pollutant Emissions Impacts of Shortline Railroad Abandonment. In *Railroad Economics*. Eds. Dennis, Scott M. and Wayne Kenneth Talley. Oxford, UK: Elsevier.

Bureau of Economic Analysis (BEA). 2009. Current-dollar and "real" gross domestic product. Washington, DC: U.S. Department of Commerce website.
http://www.bea.gov/national/xls/gdplev.xls
(last accessed 9 May 2009).

Bureau of Transportation Statistics (BTS). 2004. 2002 Commodity Flow Survey.
http://www.bts.gov/programs/commodity_flow_survey
(last accessed 21 June 2009).

Canadian Cattlemen's Association and Beef Information Centre (CCABIC). 2001. Canada's Beef Industry.
http://albertabeef.org/res/cp-beefIndustry.pdf
(last accessed 24 July 2009).

Carr, J. 1998. Garth Pig Stockmanship Standards. Sheffield, England: 5M Enterprises.
http://www.thepigsite.com/stockstds/
(last accessed 28 July 2009).

The City of New York (PlaNYC). 2007. PlaNYC 2030: A Greener, Greater New York. City of New York website.
http://www.nyc.gov/html/planyc2030/html/downloads/the-plan.shtml
(last accessed 20 July 2009).

Consolidated Edison (conEdison). 2009a. Newsroom: Electric System. Con Ed website.
http://www.coned.com/newsroom/energysystems_electric.asp
(last accessed 20 July 2009).

Consolidated Edison (conEdison). 2009b. Newsroom: Gas System. Con Ed website.
http://www.coned.com/newsroom/energysystems_gas.asp
(last accessed 20 July 2009)

Corbett, James J. 2004. Marine Transportation and Energy Use. In *Encyclopedia of Energy*, Volume 3, ed. Cleveland, Cutler. Oxford, UK: Elsevier.

Dupchak, Karen. 2009. Rations for Backgrounding Calves. Manitoba Agriculture, Food and Rural Initiatives.
http://www.gov.mb.ca/agriculture/livestock/beef/baa05s03.html
(last accessed 27 July 2009).

Economic Research Service, U.S. Department of Agriculture (ERS). 2008. Background: Cattle.
http://www.ers.usda.gov/Briefing/Cattle/Background.htm
(last accessed 25 July 2009).

Economic Research Service, U.S. Department of Agriculture (ERS). 2009a. Food Availability: Spreadsheets.
http://www.ers.usda.gov/Data/foodconsumption/FoodAvailSpreadsheets.htm
(last accessed 16 July 2009).

Economic Research Service, U.S. Department of Agriculture (ERS). 2009b. Livestock and Meat Trade Data: Meat and livestock annual cumulative year-to-date U.S. trade
http://www.ers.usda.gov/data/meattrade
(last accessed 17 July 2009).

Economic Research Service, U.S. Department of Agriculture (ERS). 2009c. Hogs: Background.
http://www.ers.usda.gov/Briefing/Hogs/Background.htm

Edmondson, William. 2004. Economics of the food and fiber system. *Amber Waves*, U.S. Department of Agriculture, February.
http://www.ers.usda.gov/Amberwaves/February04/DataFeature/
(last accessed 9 May 2009).

Energy Information Administration (EIA). 2008a. Commercial Buildings Energy Consumption Survey.
http://www.eia.doe.gov/emeu/cbecs/
(last accessed 17 July 2009).

Energy Information Administration (EIA). 2008b. Residential Buildings Energy Consumption Survey.
http://www.eia.doe.gov/emeu/recs/
(last accessed 22 July 2009).

Energy Information Administration (EIA). 2008c. Indian Point Nuclear Power Plant, New York. EIA website.
http://www.eia.doe.gov/cneaf/nuclear/page/at_a_glance/reactors/in_point.html
(last accessed 20 July 2009).

Energy Information Administration (EIA). 2009a. Annual Energy Review 2008. Washington, DC: United States Department of Energy, Report DOE/EIA-0384 (2007).
http://www.eia.doe.gov/emeu/aer/
(last accessed 16 July 2009).

Energy Information Administration (EIA). 2009b. Annual Energy Outlook 2009. Washington, DC: United States Department of Energy, Report DOE/EIA-0383 (2009).
http://www.eia.doe.gov/oiaf/aeo
(last accessed 24 April 2009).

Energy Information Administration (EIA). 2009c. End-Use Consumption of Electricity 2001. Washington, DC: United States Department of Energy.
http://www.eia.doe.gov/emeu/recs/recs2001/enduse2001/enduse2001.html
(last accessed 22 July 2009).

U.S. Environmental Protection Agency (EPA) 2007. Poultry Production Phases.
http://www.epa.gov/oecaagct/ag101/poultryphases.html
(last accessed 28 July 2009).

Eshel, Gidon and Pamela Martin. 2006. Diet, Energy and Global Warming. Earth Interactions 10: 1-17 (March 2006).
http://geosci.uchicago.edu/ gidon/papers/nutri/nutri.html

(last accessed 22 July 2009).

FAOSTAT. 2005. Statistical Database of the Food and Agricultural Organization of the United Nations.
http://faostat.fao.org/
(last accessed 28 July 2009)

Fessenden, Ford. 2008. The Big Commute, in Reverse. The New York Times, 24 February.
http://www.nytimes.com/2008/02/24/nyregion/nyregionspecial2/24Rreverse.html
(last accessed 20 July 2009).

Fiscal Policy Institute (FPI). 2007. Working for a Better Life: A Profile of Immigrants in the New York State Economy.
http://www.fiscalpolicy.org/publications2007/FPI_ImmReport_WorkingforaBetterLife.pdf
(last accessed 20 July 2009).

Fisheries and Oceans Canada (FOC), Department of Statistical Services. 2009. Commercial Landings: Summary Tables.
http://www.dfo-mpo.gc.ca/communic/statistics/commercial/landings/sum0407_e.htm

Fitzsimmons Kevin. 2000. Tilapia aquaculture in Mexico. Pages 171-183 in B.A. Costa-Pierce and J.E. Rakocy, eds. Tilapia Aquaculture in the Americas, Vol. 2. Baton Rouge, Louisiana: The World Aquaculture Society. Neel, James B. 1998. Exploring Beef Cattle. 4-H Beef Project.
http://www.ansci.cornell.edu/extension/beef/beefu1.pdf
(last accessed 26 July 2009).

Food Surveys Research Group, Beltsville Human Nutrition Research Center, Agricultural Research Service, U.S. Department of Agriculture (FSRG). 1997. Data Tables: Results from USDA's 1994-96 Continuing Survey of Food Intakes by Individuals (CSFII) and 1994-96 Diet and Health Knowledge Survey.
http://www.ars.usda.gov/Services/docs.htm?docid=14531
(last accessed 22 July 2009).

Gaines, Linda, Anant Vyas and John L. Anderson. 2006. Estimation of Fuel Use by Idling Commercial Trucks. Argonne, IL: Center for Transportation Research, Argonne National Laboratory, Paper No. 06-2567.
http://www.transportation.anl.gov/pdfs/TA/373.pdf
(last accessed 24 July 2009).

Gill, Warren. 1999. Stretching Hay Supplies to Help Get Through the Winter. Cattle Today Online.
http://www.cattletoday.com/archive/1999/November/Cattle_Today15.shtml
(last accessed 26 July 2009).

Goodband, Bob. 2009. Feeding and Feeder Management: Influences on Feed Efficiency. Paper presented at the Swine Profitability Conference.
http://www.thepigsite.com/articles/2747/feeding-and-feeder-management-influences-on-feed-efficiency
(last accessed 28 July 2009).

Hamre, Melvin L. 2008. Farm Flock Poultry. University of Minnesota Extension.
http://www.extension.umn.edu/distribution/livestocksystems/DI3605.html
(last accessed 28 July 2009).

Heller, M. C., and G. A. Keoleian. 2000. Life cycle-based sustainability indicators for assessment of the U.S. food system, Report No. CSS00-04 of the Center for Sustainable Systems, School of Natural Resources and Environment, University of Michigan, Ann Arbor, MI.

Herszenhorn, David M. 2002. The Mayor's Budget Plan: Commuters; Tax Plan for Non-residents Aims at Where the Money is. The New York Times, 16 November.
http://www.nytimes.com/2002/11/16/nyregion/mayor-s-budget-plan-commuters-tax-plan-for-non-residents-aims-where-money.html
(last accessed 20 July 2009)

Internal Revenue Service, U.S. Department of Treasury (IRS). 2002. Poultry Industry. Training Manual 3123-013 (03/2002), TPDS No. 87537E.
http://www.irs.gov/pub/irs-mssp/poultryatg12-16.pdf
(last accessed 25 July 2009).

Kohli, Pawanexh. 2000. Refrigerated Ships.
http://crosstree.info/Documents/reefer%20vessels.pdf

Lawrence, John D. and Shane Ellis. 2008. Returns from Farrowing and Finishing Hogs. Iowa State University Extension, B1-30.
http://www.extension.iastate.edu/agdm/livestock/pdf/b1-30.pdf

Leeson, Steve. 2000. Poultry: Is Feed Efficiency Still a Useful Measure of Broiler Performance? University of Guelph, Department of Animal and Poultry Science.
http://www.omafra.gov.on.ca/english/livestock/poultry/facts/efficiency.htm
(last accessed 28 July 2009).

Levay, Michael C. 2009. Pasture-to-Plate Emergy Analysis of Beef and Pork in New York City. New York: Hunter College Honors Environmental Studies Project (unpublished).

McKinley Health Center, University of Illinois at Urbana-Champaign (MHS). 2008. Macronutrients: the Importance of Carbohydrate, Protein and Fat.
http://www.mckinley.illinois.edu/Handouts/macronutrients.htm
(last accessed 17 July 2009)

NYC & Company, Inc. (NYC&CO). 2008. Research & Analytics: Research Fact Sheets.
http://www.nycgo.com/index.cfm?event=view.press&id=78830
(last accessed 18 July 2009).

National Agricultural Statistics Service, Agricultural Statistics Board, U.S. Department of Agriculture (NASS). 2007. Overview of the U.S. Turkey Industry.
http://www.agmrc.org/media/cms/usturk11092007_2CE54C8BCC490.pdf
(last accessed 28 July 2009).

National Agricultural Statistics Service, Agricultural Statistics Board, U.S. Department of Agriculture (NASS). 2008. Livestock Slaughter: 2007 Summary.

http://usda.mannlib.cornell.edu/usda/nass/LiveSlauSu//2000s/2008/
LiveSlauSu-03-07-2008_revision.pdf
(last accessed 20 July 2009).

National Agricultural Statistics Service, Agricultural Statistics Board, U.S. Department of Agriculture (NASS). 2009. Statistics by State.
http://www.nass.usda.gov/Statistics_by_State
(last accessed 23 July 2009).

National Agricultural Statistics Service, Agricultural Statistics Board, U.S. Department of Agriculture (NASS). 2009b. Poultry Slaughter Annual Summary.
http://usda.mannlib.cornell.edu/usda/current/PoulSlauSu/
PoulSlauSu-02-25-2009.pdf (last accessed 28 July 2009).

National Oceanographic and Atmospheric Administration (NOAA), National Marine Fisheries Service, Fisheries Statistics and Economics Division. 2009a. Fisheries of the United States - 2008.
http://www.st.nmfs.noaa.gov/st1/fus/fus08/index.html

National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service, Fisheries Statistics and Economics Division. 2009b. U.S. Foreign Trade (online database).
http://www.st.nmfs.noaa.gov/st1/trade
(last accessed 29 July 2009).

New York City Department of City Planning (NYCDCP). 2008. The "Current" Population of New York City: Release of Population Estimates by the Census Bureau for July 1, 2008.
http://www.nyc.gov/html/dcp/html/census/popcur.shtml
(last accessed 16 July 2009).

New York City Department of Health and Mental Hygiene (NYCDOH). 2009. Restaurant Inspection Information. NYCDOH web site.
http://www.nyc.gov/html/doh/html/rii/index.shtml
(last accessed 31 March 2009).

New York City Energy Policy Task Force (NYCEPTF). 2004. New York City Energy Policy: An Electricity Resource Roadmap.
http://www.nyc.gov/html/om/pdf/energy_task_force.pdf
(last accessed 20 July 2009).

Office of Travel and Tourism Industries (OTTI), U.S. Department of Commerce. 2009. Office of Travel & Tourism Industries' Information on Inbound Travel to the U.S.
http://tinet.ita.doc.gov/outreachpages
(last accessed 20 July 2009)

Passel, Jeffrey S. 2009. A Portrait of Unauthorized Immigrants in the United States. Washington, DC: Pew Hispanic Center website.
http://pewhispanic.org/reports/report.php?ReportID=107
(last accessed 20 July 2009)

Pelletier, N. 2008. Environmental performance in the US broiler poultry sector: Life cycle energy use and greenhouse gas, ozone depleting, acidifying and eutrophying emissions. Agricultural

Systems 98, 6773.

Pimentel, David and Marcia Pimentel. 2003. Sustainability of Meat-Based and Plant-Based Diets and the Environment. American Journal of Clinical Nutrition 78(3).

Pimentel, David and Marcia Pimentel. 2008. *Food, energy, and society.* 3rd ed. Boca Raton, FL: CRC Press.

The Port of Wilmington Deleware (POWD). 2004. Wilmington: A Distribution Hub for Lean Beef. Port Illustrated Magazine.
http://www.portofwilmington.com/HTML/our_port/port_illustrated/spring04/beef.pdf
(last accessed 24 July 2009).

PortWorld. 2009. Ship Voyage Distance Calculator.
http://www.portworld.com/map
(last accessed 24 July 2009).

Purdue University Animal Sciences Department (PUASD). 2009. Meat Quality and Safety.
http://ag.ansc.purdue.edu/meat_quality/spoiled_meat.html
(last accessed 16 July 2009).

Ramirez, C.A., M. Patel and K. Blok. 2006. How much energy to process one pound of meat? A comparison of energy use and specific energy consumption in the meat industry of four European countries. Energy 31(12): 17.

Reese, Duane E., Dennis O. Liptrap, Gary R. Parker, Gary L. Cromwell and Tim S. Stahly. 1985. Factors Affecting Feed Conversion in Growing-Finishing Swine. University of Kentucky College of Agriculture, Animal and Food Sciences.
http://www.uky.edu/Ag/AnimalSciences/pubs/asc104.pdf
(last accessed 28 July 2009).

The Truckers Report (TTR). 2008. Empty Weight of Truck and Trailer? Blog posting.
http://www.thetruckersreport.com/truckingindustryforum/questions-to-truckers-from-general-public/44744-empty-weight-of-truck-and-trailer.html

The Truckers Report (TTR). 2009. Reefer Fuel Consumption. Blog post.
http://www.thetruckersreport.com/truckingindustryforum/questions-from-new-drivers/64801-reefer-fuel-consumption.html
(last accessed 24 July 2009).

U.S. Census Bureau (USCB). 2008. Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2000 to July 1, 2008 (NST-EST2008-01).
http://www.census.gov/popest/states/NST-ann-est.html
(last accessed 16 July 2009).

Utah Beef Council (UBC). 2009. From Pasture to Plate: The Beef Production Story.
http://www.utahbeef.org/From%20Pasture%20to%20Plate_The%20Beef%20Production%20Story.pdf
(last accessed 26 July 2009).

The Vegetarian Society (VS). 2009. Information Sheet: Broiler Chickens.
http://www.vegsoc.org/info/broiler.html

Ward, G.M., P.L. Knox, and B.W. Hobson. 1977. Beef production options and requirements for fossil fuel. Science 198 (4314), 265 - 271.

Webster, Henry W. 1992. Good Genetics Are Worth The Price. Clemson University Cooperative Extension Service.
http://www.clemson.edu/psapublishing/pages/ADVS/LL50.PDF
(last accessed 27 July 2009).

"The Grass-Fed Revolution." *Time Magazine*, 11 June 2006.
http://www.time.com/time/magazine/article/0,9171,1200759,00.html
(last accessed 28 July 2009).