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Measuring and Reducing Americans' Indirect Energy Use

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Most Americans think of energy use in terms of big-ticket items such as gasoline, heating oil, and natural gas. But a great deal of the energy we use is indirect, embedded in the things we buy. Cutting down on indirect energy would produce substantial energy savings and allow Americans to continue to enjoy the lifestyle choices they have made.

High energy prices, concern over the reliability of foreign energy sources, anxiety about global warming, and an environmental ethic aimed at lessening humanity's heavy "footprint" continue to fuel widespread interest in reducing energy use. To that end, state and federal agencies and politicians of both major parties have encouraged Americans through exhortation, subsidization, and regulation to limit consumption of gasoline, heating oil, electricity, and natural gas. Public awareness campaigns to promote bicycling, subsidies for mass transit and renewable energy use, and incandescent light-bulb bans have proliferated dramatically. One major oil company, Chevron, is plastering posters throughout Washington, D.C., asking customers to use less of its product.[1] At the same time, calls for stricter vehicle fuel efficiency standards, higher appliance standards, and expanded energy efficiency labeling abound. Some environmentalists would have us go further still, encouraging people to give up air travel entirely, move to apartments powered by wind and solar energy, trade their cars for bicycles, unplug every appliance not in use, and set the thermostat higher in summer and lower in winter.

The limited success of such energy conservation campaigns reveals an unpleasant reality for fans of energy frugality: it is hard for consumers to change their direct energy use radically or quickly. Houses and cars are expensive, depreciating, long-lasting assets. Household energy efficiency modifications can be costly, unsightly, inconvenient, or all of the above. Patchwork changes may not even deliver energy benefits. For instance, installing double-paned windows in an old, poorly insulated house might result in little or no energy savings. In recent decades, the square footage of new houses has expanded. Many Americans clearly value having more space but may not be able to afford to make these larger homes more energy efficient.

Pondering the difficulties involved in cutting back on energy use led us to an offshoot of the energy literature pertaining to indirect energy use—that is, the energy embedded in virtually everything we buy. An example of this is the manufacturing and sale of a simple cotton t-shirt. Energy is required to grow and harvest the cotton; transport it to a factory; make, package, and transport the chemicals used to bleach, dye, or condition the cotton; run the machines on which the t-shirt is processed; create packaging materials; ship the t-shirt to the store; and keep the heat and lights on in the store. This is distinct from direct energy consumption, like using gasoline to run our cars, oil to heat our houses, or electricity to keep our televisions on.[2]

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There are no perfect ways to measure indirect energy use. Some use greenhouse gas (GHG) emissions as a proxy, but this is far from ideal because different forms of energy are more or less GHG-intensive. Still, even a weak measurement is better than no measurement, and the GHG approach is a useful concept of which scientists and environmentalists lately have been taking note. For instance, the U.S. Green Building Council, which certifies buildings as "green" under its Leadership in Energy and Environmental Design rating system, has been discussing how to take into account the embodied energy of building materials in its rating system.[3]

But we wondered if one could do better than the GHG proxy approach and offer Americans other options for reducing their energy consumption without incurring large upfront costs or giving up major conveniences like roomy houses and cars or even just pretty light fixtures. Using data from the U.S. Department of Commerce's Bureau of Economic Analysis, we calculated how much energy Americans use in consumption of goods not normally thought of as energy consuming, including food, consumer goods, and transportation.

What we found will surprise many people. It turns out that nearly half (46 percent) of total energy used is consumed indirectly, through production of foods, medicines, and consumer goods. The highest level of indirect energy consumption is in health care services and pharmaceuticals, and the second highest is in food production and preparation. At the other end of the spectrum, religious activities and education consume relatively little indirect energy. And what will come as a pleasant surprise for those with a somewhat more hedonistic bent, beauty products are fairly "low energy." The good news for those who want to reduce energy consumption but cannot make major lifestyle changes—such as moving from a house to an apartment, ditching the car, or not flying—is that there are unexplored options for reducing energy use.

Calculating Indirect Energy

To explore the indirect ways that people use energy, we examined input-output tables from the Bureau of Economic Analysis for 2006, the latest year for which data are available.[4] The core of the input-output accounts consists of two basic national accounting tables: a "Make" table and a "Use" table. The Make table shows the production of commodities by industry. Each row shows all the commodities produced by a specific industry with the row total being the industry's output. Each column shows the total output of a specific commodity from all industries. The Use table shows the use of commodities by intermediate and final users. In contrast to the Make table, the rows in the

How to read these tables: Total commodity output is the total dollar value, in millions, of each commodity. This counts both the commodities used as intermediate goods by industries to create something else and those used as final goods by consumers. Total industry output is the total value, in millions, of the output of each industry.

A Make Table

Industries/Commodities	Farms	Forestry	Oil and gas	Utilities	Other industries	Total industry output
Farms	244,474	7,638	0	0	2,709	254,822
Forestry	29	63,485	0	0	968	64,481
Oil and gas	0	0	227,998	0	25,289	253,287
Utilities	0	0	764	0	430,409	431,173
Other commodities	0	5,735	799	495,376	23,229,919	23,731,829
Total commodity output	244,503	76,858	229,561	495,376	23,689,294	24,735,592

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis.

A Use Table

Industries/Commodities	Farms	Forestry	Oil and gas	Utilities	Other commodities	Total commodity output
Farms	34,725	1,328	0	12	208,438	244,503
Forestry	17,060	24,954	0	0	34,844	76,858
Oil and gas	0	5	41,368	90,626	97,562	229,561
Utilities	5,116	118	1,077	171	488,894	495,376
Other industries	197,921	38,076	210,842	340,364	22,902,091	23,689,294
Total industry output	254,822	64,481	253,287	431,173	23,731,829	24,735,592

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis.

Use table present the commodities, and the columns display the industries and final users that use them. The Use table is sometimes referred to as the "recipe" matrix because it shows the components that are necessary for producing the output of each industry.

For our analysis, we began by calculating the total amount of energy used as an input in various industries from the Use table. The energy components included oil and gas, mining (including coal mining), support activities for mining, utilities (including electricity, natural gas, and water), petroleum, and coal products. This gave us the total energy used by each industry as a fraction of the total industry output. Next, we used this information to derive the total energy content of different commodities from the Make table. For instance, if the direct energy component of an industry's output is 0.5 percent, then that is used to derive the energy use for the commodity that industry helps produce. Summing across all industries for each commodity, we then calculated the total energy used in the production of each commodity. Finally, we were able to translate the energy component of different commodities into the energy component of different consumption items using the Personal Consumption Expenditure Bridge tables (also available from the Bureau of Economic Analysis).[5] These tables allowed us to include the transportation costs for each consumption item.

Once we had the total energy embodied in each consumption item, we were able to translate this into dollar terms by obtaining the total expenditure for each consumption item from the National Income and Product Accounts tables for 2006.[6] The direct energy expenditures were then calculated by summing up total expenditures on electricity, gas, water, fuel oil, coal, gasoline, and oil. The rest were classified as indirect energy expenditures.

Indirect Energy Consumption

Surprisingly, we found that the indirect energy component of America's total energy consumption is almost as large as the direct energy component. As stated earlier, indirect energy consumption represents about 46 percent of all consumption, while direct energy represents the remaining 54 percent.

As table 1 shows, the largest components of indirect energy consumption are health care (27.5 percent) and food (23.7 percent), which together comprise about half of total indirect energy consumption. This is confirmation of similar findings published in the economic literature.[7] Transportation by vehicles that consumers do not fuel directly (such as air travel, taxis, and buses) and transportation-related consumption (auto parts, motor oil, and vehicle parts) represent 12 percent of total indirect energy consumption. Activities using the least amount of indirect energy include beauty care, religion, and education.

Table 1

Indirect Energy Use by Category

	Percent of total indirect energy consumption
Health care	27.5
Food	23.7
Transportation	12.0
Housing	9.9
Entertainment	5.8
Clothing and shoes	3.7
Financials	3.4
Beauty	2.9
Religion	2.8
Education	1.5

SOURCE: Authors' calculations.

Health Care. As table 2 shows, about half (almost 47 percent) of the indirect energy consumed within health care involves the preparation of pharmaceuticals. Physician services come next, accounting for roughly 18.5 percent of health care's indirect energy use. Some of this energy consumption is undoubtedly well spent, but some of it may result from bad incentive structures that encourage doctors to use unnecessary and energy-intensive tests and machinery. In addition, prescription drug waste is extensive. As Representative Tim Murphy (R-Ohio) observes on his web site, unused medications may account for as much as $1 billion in wasted drug costs among elderly Americans each year, and waste at long-term care facilities is quite high. The value of unused drugs in long-term care facilities may be as high as $378 million, with more than 90 percent of the wasted medication due to change in prescription, death, or transfer of the resident.[8]

Food. Food consumption consists primarily of groceries and restaurant meals. Of these, the latter are the larger component of indirect energy consumption, accounting for roughly 12.5 percent of all indirect energy consump-

Table 2

Indirect Energy Use in Health Care

	Percent of total indirect energy consumption	Percent within health care
Drug preparations and sundries	12.95	46.96
Physician services	5.11	18.52
Other professional services	3.41	12.36
Medical care and hospitalization	2.34	8.50
Dentists	1.26	4.57
Nonprofit hospitals	1.02	3.69
Workers' compensation	0.38	1.38
Government hospitals	0.32	1.16
Nursing homes	0.29	1.06
Ophthalmic products	0.25	0.91
Proprietary hospitals	0.20	0.71
Income loss (insurance)	0.05	0.19

SOURCE: Authors' calculations.

Table 3

Indirect Energy Use in Food Consumption by Source

	Percent of total indirect energy consumption	Percent within food
Premade meals and beverages	12.52	52.70
Groceries	11.00	46.30
Food furnished to employees (including military)	0.20	0.90
Food produced and consumed on farms	0.02	0.10

SOURCE: Authors' calculations.

Table 4

Indirect Energy Use in Food Consumption by Type

	Percent of total indirect energy consumption
Grain mill products	19.4
Meat products	15.3
Preserved fruits and vegetables	14.0
Dairy	10.7
Beverages	10.3
Miscellaneous foods	8.0
Fats and oils	7.8
Bakery products	7.4
Sugar and confections	7.2

SOURCE: Kuo Huang, "Food Manufacturing Productivity and Its Economic Implications" (Research Brief TB-1905, Economic Research Service, U.S. Department of Agriculture, Washington, DC, November 2003), available at www.ers.usda.gov/publications/tb1905/tb1905researchbrief.pdf (accessed November 6, 2008).

tion and nearly 53 percent within the food category (see table 3). Table 4 shows how much energy infuses specific types of food. The items requiring the greatest energy to produce are grain mill products (19.4 percent), meat products (15.3 percent), and preserved fruits and vegetables (14 percent).

There is significant variance in the energy intensiveness of the production of various kinds of meat. In general, processing larger animals is less efficient than processing smaller ones. A study conducted in Sweden found that chicken had the lowest energy consumption of the types of meat studied, at 18,500 calories per pound produced. Pork and lamb had 21,000 calories and 23,000 calories per pound, respectively, and beef had energy inputs of up to 40,000 calories per pound.[9] This is a similar finding to other studies.[10]

Within the seafood category, clams are an energy bargain at 10,000 calories per pound, while shrimps without shells are staggeringly energy expensive, with 116,000 calories used to produce a pound. As with mammals, larger fish are less energy efficient than smaller ones, so eating lower on the food chain is a way to save energy. Producing four pounds of small fish like sardines and anchovies uses the same amount of energy as producing one pound of farmed salmon.[11] Eggs are another energy efficient animal product, with inputs of only 9,500 calories per pound. Vegetables are significantly more energy efficient than most forms of meat. Estimates for cooked legumes range from 2,600 to 10,560 calories per pound.[12]

In general, a vegetarian diet is more energy efficient than a nonvegetarian one, which is something that environmental groups regularly highlight. Overall, however, we found that meat consumption is only responsible for slightly more indirect energy use than fruit and vegetable consumption, and there are wide variations in how many calories it takes to produce different meats. This suggests that while growing vegetables in your backyard is certainly more energy efficient than buying beef, cutting out meat entirely may not be the most painless way for

Americans to meaningfully reduce their energy consumption.

Transportation. Airline travel accounts for almost 34 percent of the indirect energy consumed in the provision of transportation. The next highest energy consumption occurs in repair and maintenance of individual automobiles (nearly 19 percent) and in the use of other motor vehicles not directly fueled by the consumer (see table 5).

Housing. Housing turns out to be a relative bargain in terms of indirect energy consumption, accounting for less than 10 percent of all indirect energy consumption (see table 6). This includes the use of not only the physical structure of the dwelling, but items like home furnishings, furniture, china, glassware, tableware, utensils, kitchen equipment, and cleaning and polishing solutions. In fact, maintenance (cleaning, polishing, and preparation) is the second largest indirect energy consumption component after the housing unit itself.

Entertainment. Surprisingly, entertainment items such as toys, sports gear, video and audio equipment, computers, radios, and televisions use nearly as much indirect energy as household maintenance does (see table 7). Cinemas, theaters, and opera houses take up less indirect energy than sports and photographic equipment, boats, and the ownership of pleasure aircraft.

Conclusion

For a whole host of reasons, many Americans want to reduce their consumption of energy. They may care about the environment; they may want to reduce America's foreign energy dependence; they may want the moral satisfaction of knowing they have done what they can to deny their dollars to petro-barons; or, in today's troubled economy, they may simply want to live more frugally. But the main emphasis in public discussion of

Table 5
Indirect Energy Use in Transportation

	Percent of total indirect energy consumption	Percent within transportation
Airline travel	4.07	33.87
Repair, greasing, washing, parking, storage, rental, and leasing	2.23	18.55
Other motor vehicles	1.79	14.91
Insurance	1.12	9.30
New autos	0.85	7.08
Tires, tubes, accessories, and other parts	0.79	6.57
Net purchases of used autos	0.65	5.43
Mass transit systems	0.24	2.02
Other	0.10	0.83
Taxicabs	0.09	0.73
Buses	0.05	0.38
Bridge, tunnel, ferry, and road tolls	0.02	0.15
Railways	0.02	0.15

SOURCE: Authors' calculations.

Table 6
Indirect Energy Use in Housing-Related Activities and Household Goods

	Percent of total indirect energy consumption	Percent within housing
Cleaning and polishing, miscellaneous household supplies, and paper products	2.43	24.45
Owner-occupied nonfarm dwellings	2.02	20.35
Other durable house furnishings	1.21	12.15
Furniture, including mattresses and bedsprings	0.86	8.70
China, glassware, tableware, and utensils	0.65	6.59
Semidurable house furnishings	0.61	6.14
Tenant-occupied nonfarm dwellings	0.55	5.56
Kitchen and other household appliances	0.38	3.85
Telephone and telegraph	0.23	2.31
Domestic service	0.23	2.27
Rental value of farm dwellings	0.03	0.30

SOURCE: Authors' calculations.

Table 7
Indirect Energy Use in Entertainment

	Percent of total indirect energy consumption	Percent within entertainment
Commercial participant amusements	1.39	23.78
Video and audio goods, including musical instruments	1.05	18.01
Nondurable toys and sport supplies	0.92	15.68
Wheel goods, sports and photographic equipment, boats, and pleasure aircraft	0.75	12.89
Flowers, seeds, and potted plants	0.46	7.80
Computers, peripherals, and software	0.44	7.59
Clubs and fraternal organizations	0.29	4.99
Spectator sports	0.19	3.33
Theaters, opera houses, and nonprofit entertainment (except athletics)	0.18	3.11
Parimutuel net receipts	0.09	1.50
Radio and television repair	0.05	0.86
Cinemas	0.03	0.47

SOURCE: Authors' calculations.

reducing energy use has been on the big but hard-to-change items—housing, vehicles, and so on—that people in highly developed economies have historically proven reluctant to forego.

The focus on direct energy use obscures the fact that Americans have many choices when it comes to reducing their energy and environmental footprint besides cutting back on the direct use of oil, natural gas, and electricity. Those who want to reduce their energy consumption but are unable or unwilling to forego the roomier house or car can cut down on discretionary medical purchases; minimize pharmaceutical waste; cut back on air travel; and replace high-energy foods (beef and refined grain products) with lower-energy foods such as poultry, legumes, and fresh fruits and vegetables. Can we both preserve consumer choice and expand options for energy conservation? Yes, we can.

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Notes

1. To read more about the Chevron "Will You Join Us" campaign, visit www.willyoujoinus.com/.

2. The definition of direct and indirect energy used here is taken from Gilbert Metcalf, Kevin A. Hassett, and Aparna Mathur, "The Incidence of a U.S. Carbon Tax: A Lifetime and Regional Analysis," forthcoming in *The Energy Journal*, draft available at www.aei.org/publication27440/.

3. U.S. Green Building Council, "Integrating LCA into LEED: Working Group A (Goal and Scope) Interim Report #1," December 2006, available at www.usgbc.org/ShowFile.aspx?DocumentID=2241 (accessed November 6, 2008).

4. U.S. Department of Commerce, Bureau of Economic Analysis (BEA), "Industry Economic Accounts: Interactive Access to Input-Output Accounts Data," available at www.bea.gov/industry/iotables/table_list.cfm?anon=76650 (accessed October 9, 2008).

5. BEA, "Industry Economic Accounts: Underlying Estimates," available at www.bea.gov/industry/more.htm (accessed October 9, 2008).

6. BEA and Econstats, "Real Personal Consumption Expenditures by Major Type of Product Quantity Indexes," available at www.econstats.com/nipa/NIPA2_2_3_3_.htm (accessed October 9, 2008).

7. See, for example, Klaas Jan Kramer, Henri C. Moll, Sanderine Nonhebel, and Harry C. Wilting, "Greenhouse Gas Emissions Related to Dutch Food Consumption," *Energy Policy* 27, no. 4 (1999): 203–216; Annika Carlsson-Kanyama, Marianne Pipping Ekstrom, and Helena Shanahan, "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency," *Ecological Economics* 44, no. 2 (2003): 293–307; and Michael Brower and Warren Leon, *The Consumer's Guide to Effective Environmental Choices: Practical Advice from the Union of Concerned Scientists* (New York: Three Rivers Press, 1999).

8. Office of Representative Tim Murphy, "Rx: Healthcare FYI #10," available at http://murphy.house.gov/News/DocumentSingle.aspx?DocumentID=26255 (accessed November 20, 2008).

9. Annika Carlsson-Kanyama, Marianne Pipping Ekstrom, and Helena Shanahan, "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency."

10. See, for example, Annika Carlsson-Kanyama, "Climate Change and Dietary Choices—How Can Emissions of Greenhouse Gases from Food Consumption Be Reduced?" *Food Policy* 23, no. 3–4 (November 1998): 277–93; Klaas Jan Kramer, Henri C. Moll, Sanderine Nonhebel, and Harry C. Wilting, "Greenhouse Gas Emissions Related to Dutch Food Consumption"; and Michael Brower and Warren Leon, *The Consumer's Guide to Effective Environmental Choices: Practical Advice from the Union of Concerned Scientists*.

11. Taras Grescoe, "Sardines with Your Bagel?" *New York Times*, June 9, 2008.

12. The numbers from Sweden may not be broadly applicable since they come from studying supply chains and agriculture within Sweden. However, there is limited scholarship on the subject within the United States.