The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Flex-Fuel Humans

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This is a guest post by Tom Murphy. Tom is an associate professor of physics at the University of California, San Diego. This post originally appeared on Tom's blog Do the Math.

If you're one of those humans who actually eats food, like I am, then a non-negligible part of your energy allocation goes into food production. As an approximate rule-of-thumb, each kilocalorie ingested by Americans consumes 10 kilocalories of fossil fuel energy to plant, fertilize, harvest, transport, and prepare. The energy investment can easily exceed a person's household energy usage—as is the case for me. But much like household energy, we control what we stick in our mouths, and can make energy-conscious choices that result in substantial reductions of energy consumption. I now call myself a flexitarian, a term acknowledging that my body is a flex-fuel vehicle, but also that I need not be rigid about my food choices in order to still make a substantial impact on the energy front.

An earlier post on how many miles per gallon a human gets while walking or biking touched on the fact that fossil fuels undergird our food supply. As a result, walking to the grocery store effectively uses as much fossil fuel as would a typical sedan. The lesson is *not* to walk less, but to change that 10:1 ratio for the better by eating more smartly. Once upon a time, we put less than one kilocalorie of energy into food production per kilocalorie obtained (or else we and our draft animals would have starved to death). So the 10:1 ratio is not at all inescapable, and depends strongly on the foods we choose to eat.

My Flex Transition

Several years back, I engaged in a broad spectrum of energy reduction strategies. I had learned enough to know that our energy future was not likely to follow an ever-growing trajectory. The back-side of the fossil fuel age could bring with it challenges unimagined by our many-generation boom society. Technology can play an important role over the long term. But tech solutions generally do not hold a candle to voluntary reduction when it comes to having enormous short-term impacts. I was curious to know how life would be if I reduced energy use by something like a factor-of-two across-the-board. As a result, I not only have the personal satisfaction of knowing that it can be done without drastic changes in lifestyle, but I am also much better-prepared to adapt to a world where energy reduction may not be as much a choice as an imposition foisted on us by failing supply.

I had heard from multiple sources that eating meat carried a large energy tax, amounting to as much as 8× for beef, 5× for pork, and something like 2× for chicken and fish. I have not been able to track down this original source, but the sentiment was almost certainly correct if not the numerical factors. In any case, I switched to a primarily meat-free diet.

That's not to say I don't enjoy eating meat products. I personally have no ethical problems with eating meat, and still enjoy meat on special occasions or even by accident. I imagine many vegetarians feel sullied when a piece of beef slips into their otherwise vegetarian burrito. Not me. Meat treat! Accidental/unexpected bits of bacon *happen* surprisingly often, but do not go unappreciated. When I go to someone's house for dinner, I'll happily eat whatever is being served. On holidays I enjoy the traditional fare: Thanksgiving turkey (for which I *am* thankful), July 4th hot dog or hamburger, etc. And sometimes it can be hard to hew to the plan when traveling, so sometimes I switch over to meat when that's the only reasonable option.

My approach is to not let my no-meat preferences become an undue impediment to myself or to others. When I have *control* over the situation, and have good vegetarian options available (almost always), I'll go meatless. Otherwise I'll go with the flow. One trick I've learned in meat-centric restaurants is that I can often order a few side dishes that result in generous portions at a lower price than a "normal" meal.

Being semi-quantitative about it, although based on questionable numbers, I figured that maybe I got a quarter of my food energy from meat, which probably averaged 4× the energy impact of vegetarian fare. Playing this game, let's say that 75 units of energy went into my 75% vegetable-based diet, and another 100 units for the 25% meat portion. Going full-veggie would require 100 units rather than 175. So roughly speaking, I figured I was having about a factor-of-two impact. The occasional meat treat might constitute 1% of my dietary intake, and at 4× the impact, this turns 100 units of energy into 103 (99% vegetarian plus 4×1% meat). Not a big deal for the occasional deviation.

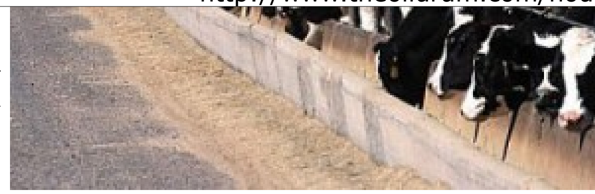
I have to admit that I have never been a big fan of vegetables themselves. But somehow I really like being a flexitarian. It feels like a responsible choice, and between pasta, bread, rice, beans, cereals, dairy products, and nuts, I do not spend my days feeling deprived of good things to eat. An alternate approach of moderation is to use meat as an accent, or garnish in a meal—constituting a very small portion of the caloric value.

An Aside About Protein

Somewhere along the way, our culture developed something of a fixation on protein. It's not as important to a healthy diet as many assume. In fact, read *The China Study* for a fascinating and compelling story recounting mountains of evidence to the contrary—especially exposing the deleterious effects of animal protein. It's not hard to get plenty of protein from plant matter. You don't really even have to be vigilant—rice and beans will do you well. Unless you're a body builder or actively increasing muscle mass, maintaining your physique requires just 10% of your calories in protein form. Billions test the idea daily, without shriveling up from lack of protein.

Other Considerations

Energy is not the only component to the story, even though it's the one I focus on here. Livestock practices in the U.S. have become ever-more industrialized, packing animals into giant feedlots, raising chickens too top-heavy to walk properly, and feeding grains to naturally grass-eating cows resulting in chronic stomach pain. Genetic engineering, waste pools, rampant antibiotics, heavy water use, and wholly unnatural lives of animals all make the modern meat industry a twisted enterprise. Although it's not a primary motivation for me, I am relieved to bear less personal responsibility for this mode of feeding ourselves.



Digging Deeper: Energetics of Food Choices

Eventually, I felt I should learn more about the impacts my choices were having. Was I fooling myself? Was I making poor choices based on erroneous information? How reliable were these 8×, 5×, etc. factors? I was pretty sure that my diet was at least going in the *right direction* with regard to energy, but should I fine-tune it based on more solid analysis?

I ran across a fascinating work by Gidon Eshel and Pamela Martin that consolidates a variety of research inputs into an assessment of the energy requirements of various diets. Much of the data comes from a book edited by Pimentel and Pimentel called Food, Energy, and Society, which has seen editions in 1996, 2005, and 2008.

First, a few numbers to lay the groundwork. Excluding exports, the U.S. produces 3774 kcal of food energy per person in the U.S. Not all of this is eaten: 2100 kcal is a more typical diet. Yes, food is wasted in the U.S. The total share of national energy devoted to food production, distribution, and preparation ranges from 10% to 17%, depending on what is included in the summation (see Heller, DoE, and Horrigan references in the Eshel & Martin work referenced above, and this USDA report). Ignoring the household portion (refrigeration, cooking), food tends to end up consuming around 11% of our energy inputs. Using the handy—if not alarming—number that each American's total energy share zips by at a rate of 10,000 W, this means 240 kWh/day is expended per person, so that food comes out to about 27 kWh/day per person in the U.S. Meanwhile, we typically metabolize 2100 kcal/day, which turns into 2.44 kWh/day. There's our 10:1 ratio: put in 27 kWh of energy, eat 2.44 kWh in exchange. (We can also get to 10:1 quickly by realizing that 11% of 10,000 W is 1100 W, while the human metabolism runs at about 100 W.)

Next, the typical American diet is broken down (calorically) as 72% plant-based, 11.5% dairy, 9% red meat, 5% poultry, 1.5% eggs, and 1% fish, in round-ish numbers.

Now for the magic part. What is the output-to-input energy ratio for producing various types of food? The following table is excerpted from the Eshel & Martin paper, much of which derives from the Pimentel & Pimentel work. One caution: don't take these numbers as absolutely authoritative. I suspect the uncertainties are quite large, but they nonetheless convey a general sense.

Food Type	Energy Out/Energy In
Shrimp	0.009
Lamb	0.012
Pork	0.037
Salmon (farmed)	0.057
Tuna	0.058
Beef (grain fed)	0.064
Eggs	0.112
Chicken	0.181
Milk	0.206
Tomatoes	0.6
Herring	1.1
Apples	1.1
Potatoes	1.2
Peanuts	1.4
Dry Beans	1.8
Rice	2.1
Wheat	2.2
Corn	2.5
Soy	4.15
Oats	5.1

Even if the uncertainties are sizable, the obvious trend is that plants and grains tend to produce more energy than is contained in the fossil fuel inputs. These numbers are for U.S. production practices, and tend to be larger by factors of two or three when manual techniques are employed.

How can eggs cost more energy than the whole chicken? Well, how long must a chicken live and be fed before it produces the equivalent of its edible body weight in eggs? Apparently longer than it needs to live and be fed to find its way to the frying pan.

Having laid some groundwork, we can now have some fun imagining various diet scenarios and computing the production energy of each set of choices. Let's use an energy factor of 2 as representative of plant-based food. Obviously then, a strict vegan (no animal products) can get by with only 1.2 kWh of fossil fuel investment to produce a day's worth of food (2.4 kWh)—becoming 2.2 kWh if we allow the typical U.S. ratio of produced/consumed food. At present, we're only talking about production and processing—later we'll address other required energy inputs for distribution, refrigeration, preparation, etc.

Meanwhile, the typical American diet has a weighted energy expenditure of 0.72/2.0 (plant) + 0.115/0.206 (milk) + 0.09/0.05 (red meat) + 0.05/0.181 (chicken) + 0.015/0.112 (eggs) + 0.01/0.05 (fish), amounting to **3.3 times** as much fossil energy as food energy. In case you are confused about where these numbers come from, the dietary fraction of any particular intake is in the numerator of each term (e.g., 11.5% from milk/dairy), and the factor of energy output/input is in the denominator (sometimes approximating a mix of inputs from the table). The vegan calculation by the same method is 1.0/2.0 (100% of food from plants, at a 2:1 output:input ratio), for a factor of **0.5**×.

So from a pure production point of view, the vegan uses *one-sixth* the energy resources that the typical American does to grow/raise food. What about someone like me who has not given up dairy/eggs? I'm not replacing all of the normal 28% animal product with dairy/eggs: I make up a good deal of the difference via grains, etc. Let's say that I am 15% dairy and 2% eggs, just for the sake of getting some numbers down. My math looks like 0.83/2.0 (plant) + 0.15/0.206 (dairy) + 0.02/0.112 (eggs) for a production energy requirement of **1.3 times** the fossil fuel input. So I'm not below the magic 1:1, but more than a factor of two less than the typical diet. I would drop to 1.15× if giving up eggs, or all the way to 0.5× if I dropped all animal products.

The Rest of the Energy

There is more to the food energy story than production and processing alone. We also have transportation (actually not that large), packaging, refrigeration, retail operations, and preparation. If the average American diet uses a production energy input that is 3.3 times the metabolic energy output of the food, and total energy inputs amount to ten times the metabolic energy, then production/processing accounts for *one-third* of the total expenditure. We'll call the non-production aspects "*overhead*," and assess this at 6.7 times the metabolic energy, so that the average American diet—consuming 3.3 times the metabolic energy for production—adds to the familiar 10× total.

If the overhead costs are the same for all types of food, then the vegan diet comes to 0.5× for production, plus 6.7× for overhead, in the end only managing to shave 30% off the energy requirements of the average American diet.

But this is likely not true. Vegan-friendly foods, for example, tend to require less packaging (see produce section of grocery store), and less refrigeration (grains, etc.). If we make a crude guess that vegan diets require half the energy in the overhead sectors, the net effect is 0.5× for production, plus 3.3× for overhead, amounting to about 40% as much energy going into food delivery as for the typical diet. It's just a rough guess, but it looks like roughly a factor-of-two in any case.

The sort of diet I'm on (allowing eggs and dairy) will likely fall in between vegan and average American on the energy overhead front. If my diet requires 75% of the overhead that a typical diet would, then I'm at 1.3× for production, plus 5× for overhead. In this case, my diet choices result in 63% of the energy that the average American consumes. Given that I tend to waste little food, perhaps I am operating below 60% on the energy scale. I am less sure of the food being wasted on my account before it ever makes it to my hands: otherwise I would claim a bigger share of savings in this sector—after all, using 2100 out of every 3774 kcal corresponds to a 44% waste.

The Net Effect & Perspective

Put in more familiar terms, we saw before that the food enterprise in the U.S. consumes 27 kWh/day per person—turning into about 75 kWh per household. Compare this to American household average daily consumption of 30 kWh of electricity (typically demanding ~90 kWh of thermal energy in power plants), 37 kWh of natural gas consumption, and 2.9 gallons of gasoline amounting to 105 kWh. Dietary choices can obviously have a sizable effect on our total energy budget.

As with many such adaptations, it is easy to make the claim that the change is too inconsequential to make a difference: that if the U.S. spends 10–15% on food practices, no game-changers are possible on the food front. "So I'll keep eating beef, thank you very much." In truth, our energy use is diverse, so game changers are only possible in across-the-board reduction strategies.

In other Do the Math posts, I have described cuts to our household energy amounting to about 20 kWh/day in natural gas, about 8 kWh/day in utility electricity (becomes > 20 kWh/day in source energy), and comparable cuts in gasoline use. Add to this the savings from two people each consuming 60% of the average 27 kWh of food energy, and our household saves another 22 kWh of energy per day. Clearly, our dietary choices represent a substantial component of our total energy reduction strategy.

Operating at about 60% of the typical food-energy allocation isn't *quite* the factor-of two cut that I typically like to achieve, but it's still pretty significant (and *may* in fact reach 50% given the large uncertainties in my crude calculation). I could go the vegan route and be more assured of making a factor-of-two difference, but this feels too restrictive given prevalent choices in today's society. Plus, I have the unfortunate pleasure of being essentially a vegetarian who doesn't actually *like* vegetables very much. It's not as dire as it sounds: bread, beans, rice, pasta, polenta, etc. form the foundation of my diet, and I don't struggle through life yearning for better.

Flexitarian Reflections

I try to strike a balance: mindfulness without rigidity; disciplined minus judgment; sacrifice without dismal deprivation; flexibility without wanton rationalization.

The main idea is what a nerd-type might call establishing a low **duty-cycle** for eating energy-intensive foods. If 2% of my meals share the profile of an average American diet (about right for my habits), then my computed 63% energy impact turns into a trivially-different 64%. At one normal American diet day per week (14% duty-cycle), it would turn into a 68% impact. I like the "Meatless Monday" movement, but would like the inverted situation of "Meat Treat Monday" even more.

The numbers sketched above indicate that big reductions are not seriously jeopardized by the occasional allowance. The biggest impact stems from changing the "normal" behavior. Even though the numbers are a little fuzzy, the approximate magnitude (and direction) of the impact is obvious enough.

This is an evolving process for me. I would like to take a deeper look at the numbers, if I get the chance. I certainly no longer view tuna and chicken as equivalent. I may need to evaluate whether or not to drop eggs (small impact, given the small share of my diet), or whether to cut back on dairy products. Should I get some chickens and feed them scraps to get my eggs for "free"—in the process learning what it really means/takes to enjoy eggs? We're growing vegetables this year. Should we expand this operation and try to get a greater fraction of our diet from home-grown food (assisted by my rainwater catchment system)?

I want to have a greater awareness of the energy cost of my food, and take a greater responsibility for the choices I make. A growing number of people are doing the same, and it will be very interesting to see where the movement leads.