We will first look at attitudes and framing, then some overarching guidelines, followed by specific quantitative assessment of energy expenditures. Readers can identify for themselves areas for potential change in their own habits and expectations.

20.3.1 Overall Framing

In the absence of a major shift in public attitudes toward energy and resource usage, motivated individuals can control their own footprints via personal decisions. This can be a fraught landscape, as some people may try to out-woke each other and others will resist any notion of giving up freedoms or comforts—only exacerbated by a sense of righteous alienation from the "do-gooders."

Some basic guidelines on effective adaptation:

1. Choose actions based on some analysis of impact: don't bother with superficial stuff, even if it's trendy.
2. Don't simply follow a list of actions or impart a list on others: choose a more personalized adventure[13] based on quantitative assessment.
3. Avoid showing off. It is almost better to treat personal actions as secrets. Others may simply notice those choices and ask about them, rather than you bringing them up.[14]
4. Resist the impulse to ask: "what should I *buy* to signal that I'm environmentally responsible?" Consumerism and conspicuous consumption are a large part of the problem. Buying new stuff is perhaps counterproductive and may not be the best path.
5. Be flexible. Allow deviations. Rigid adherence makes life more difficult and might inconvenience others, which can be an unwelcome imposition. Such behavior makes your choices less palatable to others, and therefore less likely to be adopted or replicated.
6. Somewhat related to the last point, chill out a bit. Every corner of your life does not have to be perfect. We live in a deeply imperfect world, so that exercising a 30% footprint compared to average is pretty darned good, and not *that* much different than a "more perfect" 25%. Doing a few big things means more than doing a lot of little things that may drive you (and others) crazy.
7. In the end, it has to matter to *you* what you're doing and why. It's not for the benefit of others.[15]

The first two items on the list are not easy: most people are not themselves equipped to quantitatively evaluate the impact of their choices. But some simple guidelines can help.

[13] 13: . . . resulting in a mindful pursuit and not an impersonal set of imposed chores

[14] 14: A joke illustrates the usual pitfall: "How will you know if a new acquaintance is vegan? Oh, don't worry, they'll tell you within 10 minutes."

[15] 15: . . . except, of course, in the broadest collective sense: it's for people you will never meet who are not even alive yet, and for other life on Earth you will never see.

20.3.2 Energy Assessment Principles

This section contains a number of key insights that can guide actions. Each starts with a simple statement in bold font, followed by elaboration and then an example or two[16] for most.

Heat is costly. Anything whose job it is to create thermal energy (heat) is a power-hog: clothes dryer; home heating; hot water heater; space heater. A small device called the Kill-A-Watt is handy for assessing power draw by plug-in appliances.

Example 20.3.1 How much energy does it take to dry a load of clothes using a 5,000 W clothes dryer?

Assuming it takes about an hour to run, this is 5 kWh, or 18 MJ.

Example 20.3.2 How much energy does it take to heat all the water in a 40 gal (150 L) tank from 10°C to 50°C?

Recalling Def. 5.5.1 (p. 73) or the definition of the kilocalorie, heating 150 L (150 kg) by $\Delta T = 40°\text{C}$ will take 6,000 kcal, which converts to 25 MJ or 7 kWh of energy.

How often is it on? Duty cycle matters a lot: how often it's on. A microwave oven uses a lot of power, but not so much energy, because it is hardly ever running. The Kill-A-Watt mentioned above accumulates kWh and allows determination of the average power of a device.

Example 20.3.3 How much energy is a 1,500 W microwave oven at home likely to use in a day, compared to a 25 W television tuner box running 100% of the time?

The microwave might be on for 12 minutes per day, or 0.2 hours. That makes 0.3 kWh[17] for the microwave and 0.6 kWh for the tuner box. Time matters.

Large ΔT is costly. The power it takes to maintain a temperature difference is *proportional to the temperature difference*.[18] For related reasons, a refrigerator in a hot garage has to work especially hard[19] to maintain a large ΔT.

Example 20.3.4 How much more daily energy does it take to keep a home at 25°C inside when it is 5°C outside versus keeping it at 15°C inside?

In the first case, ΔT is 20°C, while it's just 10°C in the second case. So it will take twice as much energy to keep the interior at 25°C compared to 15°C.

Use common units. Cross-comparison of energy usage is made more difficult by different units. Table 20.1 provides conversions to kWh as a

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[16] A number of the examples require some thought and estimation, which is not typical of assigned problems but may be advantageous here to promote the kind of thinking that is useful when applying to personalized situations.

[17] . . . 1.5 kW times 0.2 hours

[18] See heat loss rate and Sec. 6.3 (p. 86).

[19] . . . and at lower efficiency according to Eq. 6.10 (p. 95)

standard. In terms of power, many appliances are rated in Btu/hr, which is 0.293 W. So a hot water heater at 30,000 Btu/hr is equivalent to about 10 kW and will consume 5 kWh if running for half-an-hour, for instance. Putting everything in the same units (kWh as a suggestion here) allows useful comparisons of choices.

Table 20.1: Conversions to kWh.

Energy Quantity	kWh
1,000 Btu	0.293
2,000 kcal diet	2.3
1 L gasoline	9.7
1 kg gasoline	13
1 gal. propane	26.8
1 Therm (gas)	29.3
1 gal. gasoline	36.6

Example 20.3.5 In a month, the utility bill for a house shows 600 kWh, 20 Therms, and the two cars of the household used a total of 60 gallons of gasoline. How do these stack up, when assessed in the same units?

Using Table 20.1, the gas amounts to 586 kWh—almost identical to electricity—and the gasoline totals about 2,200 kWh, far outweighing the other two.

Electricity source matters. Your local source for electricity[20] can impact choices. It should be possible to determine your local mix via online sources [126]. The fact that conventional power plants tend to convert chemical energy into delivered electricity at 30–40% efficiency needs to be considered in comparing direct use of a fossil fuel against electrical solutions based on fossil fuel. A heat pump design for a water heater can compensate for this loss, and then some.[21]

Example 20.3.6 A hot water heater using natural gas is likely about 85% efficient at transferring the heat of combustion into the water (enclosed, insulated), while an electric hot water heater manages to get 100% of the delivered energy into the water via a heating coil immersed in the water. If the source of electricity is also natural gas form a power plant achieving 40% efficiency at converting thermal energy into electricity and then transmitting it to the house at 95% efficiency, which method uses more total fossil fuel energy, and by what factor?

We compare 85% efficient for the direct usage to 40% times 95% times 100%.[22] The ratio of 85% to 38% is 2.2, so it will take 2.2 times more gas at the power plant than in the home to produce the same result in heated water.

Weight is a guide. A rough rule of thumb is that the energy cost of consumer goods is not too far from the energy contained in the *equivalent weight*[23] *in gasoline*, meaning 13 kWh/kg (Table 20.1). Should you use paper or plastic bags? The one that weighs more probably required greater energy and resource use. Should you drive back home if you forgot your reusable bag? Compare the amount (weight) of gasoline you'll use to the weight of the disposable bags the store uses.[24] High-tech gadgets, like smart phones, almost certainly break this rule and cost far more energy to produce than their gas-equivalent weight—as can be approximated in the next point.

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[20] . . . coal vs. natural gas vs. hydroelectric, for example

[126]: Nuclear Energy institute (2019), *State Electricity Generation Fuel Shares*

[21] . . . if the COP is higher than 2.5, for instance, which it usually will be

[22] This last one is for the immersed coil, and does nothing to the answer.

[23] . . . really we mean mass

[24] . . . almost certainly *not* worth it to drive back; can you manage without any bags at all and not risk dropping anything?

Example 20.3.7 Should you buy a new, more efficient refrigerator that will use 1.8 kWh per day (75 W average) instead of your current one that uses 2.4 kWh/day (100 W average)?

At a mass around 150 kg, the refrigerator's manufacture might require ~2,000 kWh,[25] taking about 9 years to pay back at the 0.6 kWh/day saving. This is long enough that considerations such as material resources and disposal might tip the scale against replacement.

Cost is a guide. A secondary approach to figuring energy content is to suspect that the item's cost is appreciably greater than the cost of the energy that went in. Perhaps a reasonable number is that 15% of the total cost goes toward energy.[26] Conveniently, a typical retail price of electricity of $0.15/kWh then translates to 1 kWh for each $1 of consumer spending. When results from the two approaches (by mass or by price) differ, the higher energy cost number may be the safer bet.

Example 20.3.8 What do the two methods say about a 1,500 kg car that costs $25,000 and a smart phone that costs $1,000 and has 200 g of mass?

The car estimates are 1,500 kg times 13 kWh/kg for about 20,000 kWh or $25,000 times 1 kWh/$ for 25,000 kWh. In this case, they're pretty close and it hardly matters which one we favor.

For the phone, the mass estimate is just 2.6 kWh, but by price it would be 1,000 kWh. In this case, for reasons argued above, the larger one is more likely on target.[27]

Focus on the big. Keep your eye on the big impacts. We are not actually under threat of running out of landfill space, for instance. So while recycling is a preferred approach,[28] very visible in society, and should be practiced when possible, the impact is not dramatic: it still takes a lot of energy to process recycled goods. Metal recycling (especially aluminum) is most effective from energy and resource standpoints, and paper from a resource standpoint (trees), but plastic is less clear on both energy and resource bases. Reducing its use may be best.

Example 20.3.9 How effective is it to buy a water bottle for my daily needs?

Compare the weight and cost of the water bottle to the weight and cost of all the plastic cups it displaces[29] as a reasonable guide to the relative impact.

The best of all worlds is not buying something for the purpose, but finding something you *already have* that will get the job done.

Reduction rules. Reduction is by far the action with the biggest impact. Buy less stuff. Live more simply. Travel less often and less far.[30] Adapt

[25] . . . 150 kg times 13 kWh/kg

[26] This is not a capricious estimate, as it is approximately representative of energy costs in our society as a whole—stacked a little higher here to better reflect manufacturing activities, which are bound to be more energy-intensive than the economy as a whole. Also note that energy intensity, as seen in Fig. 2.2 (p. 19), is characteristically around 5 MJ/$, which is 1.4 kWh/$ and not far from our rule of thumb here.

[27] We would not go so far as to say that either method is "right." They should be viewed as very approximate guidelines that at least can help differentiate big deals from insignificant things.

[28] Better yet is to try getting by without purchasing items that require later disposal.

[29] Consider the duration of ownership or of usage and how many disposable cups are avoided.

[30] A side benefit to these actions is saving money, maybe working less hard and retiring earlier.

yourself better to the climate.[31] Eat more responsibly. The next section digs into related actions in more quantitative detail.

20.3.3 Quantitative Footprint

A useful exercise is to compare your own energy footprint to national averages. How much more or less are you using? For some categories, information is hard to assess. For instance, how much oil is used to transport the goods you buy and the food you eat? How much energy is used in the industrial and commercial sectors on your behalf?[32] In part, your level of consumerism is a good clue, but it still may be hard to compare to others. The following items offer some guidance. The first two entries can be derived from Fig. 7.2 (p. 105), after unit conversions and dividing by the U.S. population.

Electricity: A typical American uses 12 kWh of electricity per day in their residence. To get your own share, look at an electricity bill for your residence and divide by the number of people living in the place and by the number of days[33] in the billing period.

Example 20.3.10 In 2019, the author's utility bills[34] indicate total use was 3,152 kWh for a household of two. What is the daily average per person and how does it compare to the national average?

3,152 kWh divided by 365 days and 2 people is 4.3 kWh per person per day, about one-third of the national average.

Natural Gas: A typical American uses about 13 kWh of natural gas per day in their residence, amounting to 0.44 Therms per day.[35] To get your own share, look at a gas bill for your residence, if applicable, and divide by the number of people living in the place and by the number of days in the billing period.

Example 20.3.11 In 2019, the author's utility bills[36] indicate total use was 61 Therms for a household of two. What is the daily average per person and how does it compare to the national average?

61 Therms divided by 365 days and 2 people is 0.084 Therms (2.4 kWh) per person per day, about 20% of the national average.

Gasoline: A typical American buys about 400 gallons of gasoline[37] per year for personal transportation, amounting to a daily equivalent of 41 kWh[38] of energy use. Keep track of your fuel purchases[39] and compare how much you use. In the case of multiple occupancy in the car, your share can be computed by dividing how many gallons were used in the trip by the number of people. Knowing an approximate fuel economy[40] for the car and distance traveled is enough to estimate fuel usage.

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[31] It is okay to put on more clothes and sit under blankets in a cooler winter house.

[32] Wouldn't it be great if consumer goods had labels revealing embedded energy and resulting CO_2?

[33] . . . usually a month: about 30 days

[34] See the banner image on page 68 for a one-month sample.

[35] . . . typical billing unit; one Therm is 29.3 kWh; see Table 20.1

[36] See the banner image on page 68 for a one-month sample.

[37] Personal transportation accounts for about 65% of gasoline in the transportation sector.

[38] . . . 36.6 kWh per gallon, or 9.7 kWh/L

[39] This practice is good for tracking fuel economy as well.

[40] . . . e.g., miles per gallon or L/100 km

Example 20.3.12 The author's household has two vehicles,[41] one of which drove 400 miles and used 22 gallons of gasoline in 2019, and the other covered 8,660 miles using 69 gallons. What is the daily average use per person in the household, and how does this compare to the national average?

A total of 91 gallons for two people is about 45 gallons per person, equivalent to 4.5 kWh/day, and 11% of the national average.

Air travel: Expressing an average in this case is inappropriate, as many Americans do not fly at all, while all use some combination of electricity, gas, and gasoline in some capacity. The average works out to 2,300 miles (3,700 km) per year when averaging all people, but among those for whom air travel is a utilized, the number is generally a good bit higher. To put it in context and enable useful comparisons, we will compare it to ground transportation.

Typical passenger jets get approximately 90 miles per gallon (m.p.g.) *per seat*[42] (2.6 L/100 km) for a fully-occupied plane—worse if seats are empty: down to 45 m.p.g. per passenger if half full, for instance. So traveling 1,000 km in a full airplane uses the same amount of fossil fuel energy per person as driving the same 1,000 km in an efficient doubly-occupied car that gets 45 m.p.g. (5.2 L/100 km). For an 80% full airplane,[43] the effective per-passenger mileage is about 70 m.p.g., coming to an energy cost of about **0.5 kWh per mile (0.32 kWh/km) per passenger**. Because air travel tends to involve *long* trips, the energy used (thus CO_2 emissions) for air travel can easily exceed that for personal car usage, as is seen in the next example.

Example 20.3.13 The author, in 2019, flew about 4,200 miles for personal travel and 9,600 miles work-related. How many kWh per day does this translate to in the two categories, and how does it compare to expenditures in electricity, gas, and personal gasoline?

For personal air travel, 4,200 miles times 0.5 kWh per mile is 2,100 kWh or 5.8 kWh/day, which is slightly larger than the 4.3, 2.4, and 4.5 kWh/-day from electricity, natural gas, and personal gasoline computed in previous examples, but still really in the same ballpark. Business travel[44] accounts for 13 kWh/day, *by itself* exceeding the sum of household expenditures.

Example 20.3.14 If three people are traveling from San Diego to San Francisco at a distance of 700 km, how good does the car's gas mileage need to be to beat an 80% full airplane that would get 90 miles per gallon per passenger if full?

Being 80% full knocks the effective fuel economy down to 72 m.p.g. per passenger. For the three people in question, a car achieving 24 m.p.g. (9.8 L/100 km) will match the airplane's energy expenditure, so

Note that we didn't need the distance. This may seem like a "trick," but consider that life is even trickier: real-world problems have no (or maybe *all available*) information provided, and it's up to us to sort out what's relevant.

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[41] . . . a non-commuting truck and a commuting plug-in hybrid that mostly uses electric drive, charged at home (the electrical demand for which is represented in Example 20.3.10)

[42] The airplane as a whole gets less than *one* mile per gallon, but each passenger's share of gallons used makes it better on a *per-passenger* basis. It takes almost the same amount of energy to fly a plane from point A to point B independent of passenger load. Most of the energy is used to fight air resistance, which is related to the size and speed of the airplane, essentially independent of the number of passengers inside.

[43] . . . guessing this to be typical

[44] Ugh. Wish I didn't have to.

anything getting better performance will deliver the three people at a lower energy cost.

Diet Impacts: Modern agricultural practices result in a 10:1 energy expenditure on the production, distribution, and waste of food—so that each kilocalorie of food eaten requires 10 kcal of energy input [97]. A typical 2,100 kcal/day diet translates into 2.4 kWh/day, and applying the 10:1 ratio means that about 24 kWh of energy input is required to cover a typical American's diet—which is substantial on the scale of residential/personal energy use. Because food is also grown for livestock and poultry, then those animals convert the food to meat at some low efficiency, raising animals for meat is a net energy drain: directly eating the grown food ourselves[45] would use less energy and fewer resources.

20.3.4 Dietary Energy

This last point on food energy deserves some elaboration, setting the stage for a quantitative evaluation of diet choices. For any food type, it is possible to characterize the amount of energy spent producing the food as a ratio to the metabolic energy contained in the food.[46] Key results of some such studies ([127] and [128]) are provided in Table 20.2. Treat these as *rough* guides rather than absolutely definitive numbers, since specific agricultural, feeding, or fishing practices play a huge role in the energy requirements: large variations can be expected, in practice. All the same, fruits and vegetables consistently require small energy expenditures relative to meat and dairy products.

Category	Type	Ratio	Distrib.	Category	Type	Ratio
Red Meat	Lamb	83	1.8%	Plant-based	Tomatoes	1.67
	Pork	27	62.6%		Apples	0.91
	Beef	16	35.6%		Potatoes	0.83
Poultry	Chicken	5.5			Peanuts	0.71
Fish	Shrimp	110			Dry Beans	0.65
	Salmon	18			Rice	0.48
	Tuna	17			Wheat	0.45
	Herring	0.9			Corn	0.40
Dairy/Egg	Eggs	8.9	11%		Soy	0.24
	Milk	4.9	89%		Oats	0.20

Table 20.2: The ratio of energy invested in producing various common foods to the metabolic energy delivered by the food (sort-of an inverse EROEI), broken into five categories. High ratios indicate large energy costs. When known, the distribution *within* the category is given for standard American diets. Beef is grain-fed, salmon is farmed, and milk is a stand-in for dairy products more generally. Data synthesized from [127, 128].

Let's be clear about what Table 20.2 says. The production of 100 kcal of rice requires an input of 48 kcal, making it a net energy gain. Meanwhile, 100 kcal from beef takes 1,600 kcal of energy to produce, as an energy loser. Lamb and shrimp are very costly, while herring is a steal. It may seem surprising that eggs require more energy input than chicken,[47] but consider that it takes longer for a chicken to produce its weight in eggs than for a chicken to get large enough to be processed for meat.

Armed with this information, it is possible to assess a dietary energy factor[48] for various dietary choices.

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[97]: Pfeiffer (2006), *Eating Fossil Fuels*

[45] . . . preferably in not exactly the same form!

[46] In this sense, it is the inverse of EROEI: energy *invested* to extract the food divided by energy *delivered*.

[127]: Eshel et al. (2006), "Diet, Energy, and Global Warming"

[128]: Pimentel et al. (2007), *Food, Energy, and Society*

[47] Owning egg-laying chickens and feeding them scraps is a delightful win, however.

[48] "Dietary energy factor" is a term used in this textbook; not likely to be found elsewhere.

Definition 20.3.1 *The* ***dietary energy factor*** *is a weighted sum of individual energy ratios for food categories:*

$$\text{d.e.f.} = f_\text{v} \cdot R_\text{v} + f_\text{rm} \cdot R_\text{rm} + f_\text{f} \cdot R_\text{f} + f_\text{p} \cdot R_\text{p} + f_\text{d} \cdot R_\text{d}, \qquad (20.1)$$

where f_x factors are the fraction of one's diet in form "x," in energy terms (calories; kcal), and R_x values are the aggregated relative energy ratios for food category "x," as found in Table 20.3. Subscripts indicate vegetables, red meat, fish, poultry, and dairy/eggs, respectively. Note that care must be exercised to insure that all five f_x factors add to one.

Category	Energy Ratio	Relative Ratio, R_x	American Diet, f_x	Lacto/Ovo Diet, f_x	Vegan Diet, f_x	Poultry Diet, f_x
Plants	0.65	1	0.72	0.80	1.0	0.72
Red Meat	24	37	0.09			
Fish	36	55	0.01			
Poultry	5.5	8.5	0.05			0.15
Dairy/Egg	5.3	8	0.13	0.20		0.13
d.e.f.			6.1	2.4	1.0	3.0

Table 20.3: Dietary energy factor computations for various diets. Energy factors are aggregations over categories from Table 20.2, assuming equal distributions when unknown (e.g., each fish type is 25% and each plant type is 10% of that category's intake). The net effect, at bottom, is a weighted sum of the individual energy ratios, and spans large factors in terms of energy impact.

In Table 20.3, the first column of numbers is a weighted average of factors from Table 20.2, using the distribution weights listed where available, and assuming equal spread otherwise. The next column scales the energy ratios so that the vegetable category has $R_\text{v} = 1$,[49] making the dietary energy factor a measure of energy requirements *relative to* a strictly plant-based diet. For instance, red meat requires 37 times as much energy as vegetable matter, for the same metabolic energy content.

What follows in the table are four diet types, reflecting the average American diet and three variants, each having its own set of f_x factors.[50]

Example 20.3.15 Let's replicate the American diet result in Table 20.3 using Eq. 20.1.

Using $f_\text{v} = 0.72$, $f_\text{rm} = 0.09$, $f_\text{f} = 0.01$, $f_\text{p} = 0.05$, and $f_\text{d} = 0.13$, then $R_\text{v} = 1$, $R_\text{rm} = 37$, $R_\text{f} = 55$, $R_\text{p} = 8.5$, and $R_\text{d} = 8$, the dietary energy factor computes to $0.72 + 3.33 + 0.55 + 0.425 + 1.04 = 6.07$, confirming the final row. By breaking things out this way, the red meat category stands out as contributing more[51] than any other category.

Compared to a strictly plant-based (vegan) diet, the typical American diet requires about six times the energy. Since the average American diet accounts for 24 kWh per day, a vegan diet is therefore down to 4 kWh/day. A vegetarian diet partaking of dairy and eggs (lacto-ovo diet) is 2.4 times[52] the vegan diet, or a little less than 40% of the American diet (about 9 kWh/day). Just replacing all meat consumption with chicken (final column) cuts energy demand in half. These are just a few of the countless examples that may be explored using Eq. 20.1 or variants thereof to evaluate the energy impact of dietary choices.

Get on it! Evaluate your own diet and how you might modify it.

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[49] The second column of numbers is the first column divided by 0.65.

[50] Note: contrived to add to 1 in each case.

[51] Red meat is 3.33, which is 55% of the total energy cost while providing only 9% of the dietary benefit.

[52] The actual number depends on the fraction of calories coming from dairy/eggs (f_d), and can be dialed at will: it's not stuck at exactly 2.4.

Example 20.3.16 What is the dietary energy factor for a diet in which one-third of caloric intake is from red meat, 10% is from dairy/eggs, and the rest is plant matter?

Setting $f_{\mathrm{rm}} = 0.33$ and $f_{\mathrm{d}} = 0.10$, we require that $f_{\mathrm{v}} = 0.57$ in order that all three sum to 1.0. Now using $R_{\mathrm{rm}} = 37$, $R_{\mathrm{d}} = 8$, and $R_{\mathrm{v}} = 1$, the dietary energy factor computes to $12.2 + 0.8 + 0.57 = 13.6$ for red meat, dairy, and vegetable matter, respectively. This diet requires more than twice the production energy as a standard American diet.

It is possible to abandon Eq. 20.1 and roll your own formulation following similar principles. Rather than adopt the distributions from Table 20.2, the technique can be customized to any diet for which energy factors can be found.

Example 20.3.17 A diet that is 35% rice, 35% wheat, 15% corn, 10% milk, and 5% chicken has an energy cost of $0.35 \cdot 0.48 + 0.35 \cdot 0.45 + 0.15 \cdot 0.40 + 0.10 \cdot 4.9 + 0.05 \cdot 5.5 = 0.17 + 0.16 + 0.06 + 0.49 + 0.28 = 1.15$. This has not been normalized to $R_{\mathrm{v}} = 1$ yet,[53] so we divide by the aggregate 0.65 value for the plant energy ratio found in Table 20.3 to get a dietary energy factor 1.8 times that of a strictly plant-based diet. Note from the sum that milk and chicken are the largest two contributors, despite being a small fraction of the diet.

The 10:1 input:output energy ratio mentioned at the beginning of this diet segment may at first glance not square with the whole-diet energy factors computed here (e.g., a factor of 6 for the typical American diet). Missing is **food waste**. The U.S. produces 1.8 kcal of food value for every 1 kcal consumed [127]. This amount of waste may be hard to fathom, but consider waste at restaurants, cafeterias, and grocery stores when perishable items are not consumed before health standards suggest or require disposal. Still, this is an area ripe for improvement.

[127]: Eshel et al. (2006), "Diet, Energy, and Global Warming"

20.3.5 Flexitarianism

Echoing Point #5 in the list in Section 20.3.1, it is worth pointing out that energy and resource concerns are a largely *quantitative* game. One need not become a strict vegan to affect energy demands substantively. For instance, eating meat one meal a week,[54] and tending to stick to poultry when doing so would drop the energy factor of Eq. 20.1 to a value so near to 1.0 that the difference is of little consequence.

Example 20.3.18 For instance, if one meal per week, or about one in 40 of your meals looks like the last column in Table 20.3—72% plant-based and the rest poultry and dairy—what is the dietary energy factor for this diet?

Since only one in 40 meals is of this type, multiply the poultry and

[53] In other words, if performing the same sort of calculation for 10% contributions from each of the ten plant-based foods in Table 20.2, the raw result would be 0.65.

[54] . . . out of about 40 meals

dairy contributions by $\frac{1}{40}$ and adjust f_v to bring the total to 1.0. Doing so yields $f_\mathrm{v} = 0.993$, $f_\mathrm{p} = 0.00375$, and $f_\mathrm{d} = 0.00325$. Multiplying by the respective R_x values and summing produces 1.05.

Thus, the one meal of poultry/dairy per week achieves 99% of the journey from normal-American (6.1) to full vegan (1.0), from an energy perspective.

The result of Example 20.3.18 is so nearly 1.0 that it is essentially indistinguishable from a purely plant-based diet, quantitatively. This is especially true in the context that the rule-of-thumb factors are themselves not to be taken literally as high-precision numbers. All pork will not have an energy ratio of 27.0. All tuna will not be 17.0. All wheat will not be 0.45. The methods of producing the food—of all types—become important at this stage. Note that gardening (and canning) one's own food is a way to nourish ourselves at a super-low resource burden—undercutting the nominal vegan energy factor even further.

The quantitative focus suggests an approach best called flexitarianism. If energy and resources are the primary concern, rather than ethical issues around eating meat,[55] then the occasional meat treat is no big deal. Under this scheme, it is still possible to enjoy traditional foods on special occasions like holidays.[56] If a friend serves meat at a dinner party, just do the quick calculation and realize that you can easily offset later[57] and make this special-occasion meal disappear into the quantitative noise. The perception you generate is therefore more likely to be as a grateful friend, rather than as a person whose needs are difficult to satisfy.

More people are likely to be attracted to join in responsible behaviors if they are not too rigid or strict. Imagine ordering a bean, rice, and cheese burrito only to take a bite and discover a morsel of meat inside. Score! Meat Treat! It doesn't have to be a bad thing, if resource cost is what matters most. This flexibility can also apply to waste food. Before watching meat get thrown into the trash, intercept with your mouth. From a resource point of view, *wasting* meat—or any food, really—is also something we should strive to avoid: better that the energy investment produce metabolic benefit than be utterly wasted.

20.3.6 Discretionary Summary

We don't have direct and immediate control over all the energy expenditures made on our behalf in the same way that we have control over our own light switches and thermostats. Yet, we must accept our communal share of energy and resources used by governmental, military, industrial, agricultural and commercial sectors providing us with structure, protection, goods, and services. The 10,000 W average American power frequently used as a benchmark throughout this book—and mapping to 240 kWh per day—is not all in our direct control. Individuals can make

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[55] 55: . . . valid in its own domain

[56] 56: . . . arguably making them *more* special

[57] 57: . . . or note that you have already offset it by prior actions

political, consumer, and dietary choices that exercise limited control over these distant activities, but effects are small and gradual.

Table 20.4: American average and author's 2019 expenditures energy on a daily average basis expressed in kilowatt-hours.

Sector	American (kWh)	Author (kWh)
Electricity	12	4.3
Natural gas	13	2.4
Gasoline	41	4.5
Air travel	3.2	5.8
Diet	24	9
Total	93	26

Of the things that *are* under our discretion, as discussed in the sections above, Table 20.4 summarizes the average American values and those of the author in 2019.[58] Recall that the average American air travel corresponds to just 2,300 miles (3,700 km) per year. If adding consumerism to the personally-controlled energy toll, perhaps an average American spends \$10–20,000 per year[59] on "stuff," which would amount to another 25–50 kWh per day if using the rule-of-thumb 1 kWh/\$ from Section 20.3.2.

Combining the discretionary factors in Table 20.4 and a consumerism estimate, Americans have direct control over about half of their total energy footprint.[60] As the author demonstrates, it is possible to make drastic cuts to this portion—in this case a factor of three lower than average. Mostly, this comes about by a combination of awareness, caring, and tolerance for a simpler life without every possible comfort.

Box 20.2: Out of Our Control

Many energy expenditures are part of a consensus social contract that individuals cannot easily control. Examples would be lighting and interior temperature control policies for large common spaces like office buildings, campuses, libraries, and airports, for instance. Likewise for street lighting in neighborhoods and along highways. Only by large scale shifts in values would the community potentially prioritize energy and resource costs over financial cost or public health and safety.

20.4 Values Shifts

In the end, a bold reformulation of the human approach to living on this planet will only succeed if societal values change from where they are now. Imagine if the following activities were frowned upon—found distasteful and against social norms:

1. keeping a house warm enough in winter to wear shorts inside;

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[58] . . . only counting personal travel, and a mostly vegetarian (though not vegan) diet.

[59] The author might guess \$5,000 for himself as an upper limit, or another 13 kWh per day in this mode.

[60] Recall: 240 kWh per day total.