Case Study 03: How Much Energy Do You Use?

At 1.32×10^5J, it's about 25% of your energy requirements for the day!

Introduction

How much energy will you use today? Do you have any idea at all? According to the US Energy Information Administration, total energy consumption in the year 2022 (the latest year for which we have statistics) was 100,000 trillion BTU (a British Thermal Unit = BTU = energy to raise one pound of water by 1°F). Let's be clear: that's 1.0×10^{17}BTU. How much of that energy was your share?

Let's round the US population to 330 million people (or 3.3×10^8 people). Divide the total energy by the total population to calculate your personal share:

$$your\ share = \frac{energy}{population} = \frac{1.0 \times 10^{17}\text{BTU}}{3.3 \times 10^8} = 3.03 \times 10^8\text{BTU}$$

That's 282 million BTUs, but how many Joules is that?

$$your\ share = 3.03 \times 10^8\text{BTU}\left(\frac{1055\text{J}}{1\text{BTU}}\right) = 3.197 \times 10^{11}\text{J}$$

Let's round that to 320 billion Joules. That's billions-with-a-b! Still confused? Me, too. Let's also recall that $1\text{J} = 0.239\text{cal}$, and that $1000\text{cal} = 1\text{kCal}$, which are the food calories we're used to seeing on restaurant menus and nutrition labels:

$$your\ share = 3.20 \times 10^{11}\text{J}\left(\frac{0.239\text{cal}}{1\text{J}}\right)\left(\frac{1\text{kCal}}{1000\text{cal}}\right) = 7.6 \times 10^7\text{kCal}$$

So that's 76 million food calories. Now, obviously you did not eat 76 million calories of food (that would have been about 150,000 Big Macs, plus all the Diet Coke you can drink!) in the year 2022. A typical person needs about 2000kCal per day, or

$$food\ intake = \left(2000\frac{\text{kCal}}{\text{day}}\right)\left(\frac{365\text{day}}{\text{year}}\right) = 730,000\frac{\text{kCal}}{\text{year}}$$

which is right around one percent of your estimated share of the energy. You very likely did consume about that many calories, plus or minus depending on several factors: Men tend to require more calories than women, and active people need more calories than sedentary people. But what about the other ninety-nine percent? Do you really think that you personally used 320 billion Joules of energy over the course of a year? How can you find out?

You can't easily measure your total energy consumption directly, but you can make a very reasonable estimate using the documentation of your daily life. That 320 billion Joule figure is too high: You did not use *that* much energy last year, because the EIA statistics includes energy used commercially and industrially as well as residentially. So how much energy *do* you use?

Direct vs Indirect Energy Use

Let's differentiate between direct and indirect energy use. Our food intake example above is a pretty clear example of direct energy use. Your body needs fuel to function, and the calories you eat provide that fuel directly.

1. List at least three other ways in which you are a direct user of energy.

What does it mean to use energy indirectly? Here's one example: Let's say that you go to your favorite restaurant for a meal. You order your favorite plate of food, which according to the menu contains 500 food calories, and costs $10.00. Are you paying $10.00 for 500kCal, which is just two pennies per food calorie? That sounds like a bargain, and literally, you would think so. But the price tag for that plate of delicious tacos doesn't just pay for the food. It's also helps pay for the all the expenses associated with running a restaurant, and many of those expenses are energy or energy-related.

2. List at least three ways in which you are indirectly using (and paying for) energy as you enjoy your lunch in the restaurant.

3. List at least one other example of your own indirect energy use.

Photo by Deborah Rainford on Unsplash

Direct Energy Use: Electricity

How do you read this thing?

Electricity is probably the most immediately obvious of your direct energy usage. It's hard to imagine getting through a day without using electricity. On the rare occasions when we have power outages, we tend to feel its absence pretty acutely. How much electricity do you typically use? You'll need at least one month's electric bill. A better picture of your typical use would be to collect several statements. Ideally, using one from each season will give you the best overall average for your typical energy use, given that everyone uses more or less electricity depending on the season.

How is your electricity usage reported? You should see your monthly usage listed in KWh, or kilowatt-hours. What? Remember that $power = \frac{energy}{time}$, which means you can express energy as $energy = power \times time$. A Watt $= \frac{\text{Joule}}{\text{second}}$ is the standard metric unit of power, and when you multiply it by time, you will get units of energy. But why multiply by hours? Who even knows?! Grab your time machine and head back to 1906 London for the International Electric Units and Standards Convention, and

maybe you can get an answer from those guys. For the sake of simplicity (and uniformity), let's get those kWh into the standard metric Joules:

$$1\text{kWh}\left(\frac{1000\frac{\text{Joules}}{\text{sec}}}{1\text{kW}}\right)\left(\frac{3600\text{sec}}{1\text{hour}}\right) = 3.6 \times 10^6\text{J} = 3.6\text{MJ}$$

4. If you are using multiple electric bills, begin by averaging the total use and its cost.
5. If you share a residence, assume everyone uses electricity equally (even though it probably is not true) and note the total number of people in the household.
6. Calculate the average energy use in kWh and the average cost of the electricity.
7. Calculate the average number of days per billing cycle (if you are using multiple bills).

Use the example provided to complete the table. Follow the formulas carefully, because we will be performing different unit conversions at each step of the process!

Month	month	Total Consumption (kWh)	total	Daily Use (MJ/day)	$energy = MJ \div days$
	March		2630		$9468 \div 31 = 305$
Billing Period (days)	days	Total Consumption (MJ)	$MJ = total \times 3.6$	Your Share (MJ/day)	$electricity = energy \div people$
	31		$2630 \times 3.6 = 9468$		$305 \div 2 = 153$
Total Bill ($)	bill	Cost per MegaJoule ($/MJ)	$cost = bill \div MJ$	Daily Cost ($)	$daily = electricity \times cost$
	236.19		$236.19 \div 9468 = 0.025$		$153 \times 0.025 = 3.82$

8. What do you think is the biggest use of electricity in your house? Does this remain constant year-round, or does the pattern of major consumption change depending on the time of the year?
9. If you are estimating your energy use for an entire year, does this calculation for electricity use need to be revised up or down?

Direct Use: Natural Gas

American homes frequently use natural gas for central heating, hot water heaters, gas ranges, and sometimes gas dryers. Your home probably has some combination of electric and natural gas appliances. For example, my home has a natural gas furnace for central heating, a gas hot water heater, but an electric range and an electric dryer.

10. Where in your house or apartment are you using natural gas?
11. Is your gas usage seasonal? That is, do you notice a significant change in your use during different seasons?
12. Like the electric bill, you will get a better picture of your energy use when you average multiple bills covering each season. Which four months do you think would be best to use?

How do you read this thing? Same way you read the previous thing!!

Look at your gas bill and notice your that your usage is reported in ccf. What is a ccf? It's a measurement of volume: $1\text{ccf} = 100\text{ft}^3$. Okay, but we know that volume isn't energy! How much energy is released when you burn natural gas? According to the U.S. Energy Information Administration, burning 1ccf of natural gas releases 103,700BTU of energy. In Joules:

$$103,700\text{BTU}\left(\frac{1055\text{J}}{1\text{BTU}}\right) = 109 \times 10^6\text{J} = 109\text{MJ}$$

13. Use the example provided in the table below to calculate your own daily use and cost for natural gas. Follow the formulas carefully!

Month	month	Total Consumption (ccf)	total	Daily Use (MJ/day)	$energy = MJ \div days$
	March		55		$5995 \div 31 = 193$
Billing Period (days)	days	Total Consumption (MJ)	$MJ = total \times 109$	Your Share (MJ/day)	$gas = energy \div people$
	31		$55 \times 109 = 5995$		$193 \div 2 = 97$
Total Bill ($)	bill	Cost per MegaJoule ($/MJ)	$cost = bill \div MJ$	Daily Cost ($)	$daily = gas \times cost$
	94.78		$94.78 \div 5995 = 0.016$		$97 \times 0.016 = 1.55$

14. If you are estimating your typical energy use for an entire year, explain why this calculation for natural gas might need to be revised up or down.

Direct Use: Gasoline (or Diesel!)

You probably drive a car (or motorcycle, or scooter) on an almost-daily basis, such is the necessity of modern life in America. You may even routinely use more than one vehicle. Let's keep things simple by assuming you use a single vehicle, so choose whichever

Units matter!! We'd all panic a little if the pump showed $4000 to fill up!!

car (truck, motorcycle, etc) you use most frequently and use it to complete your analysis. Now that you have done this a few times, you should be able to identify the information you need to determine your average use and cost!

15. What information will you need to assemble?

16. How much information will be enough? Does your usage remain constant all year round, or do you have certain times of year when you know you drive more (or less) than average? How many months data do you think will be adequate to give a good average?

When you buy gasoline or diesel, you buy it by the gallon. Again, a unit of volume, not energy! One more time, we convert the units. According to the Environmental Protection Agency, one gallon of gasoline releases:

$$1\text{gallon}\left(\frac{113,000\text{BTU}}{\text{gallon}}\right)\left(\frac{1055\text{J}}{1\text{BTU}}\right) = 119 \times 10^6\text{J} = 119\text{MJ}$$

and one gallon of diesel fuel releases: $1\text{gallon}\left(\frac{129,500\text{BTU}}{\text{gallon}}\right)\left(\frac{1055\text{J}}{1\text{BTU}}\right) = 137 \times 10^6\text{J} = 137\text{MJ}$

17. Use the example provided in the table below to calculate your own daily use and cost for fuel. Follow the formulas carefully!

Average Daily Miles	$miles$	Daily Consumption (gal)	$gallons = miles \div mpg$	# of Commuters in Car	$people$
	6		$6 \div 15 = 0.40$		1
Average Fuel Mileage (mpg)	mpg	Daily Consumption (MJ)	$MJ = gallons \times 119$	Your Share (MJ)	$fuel = MJ \div people$
	15		$0.40 \times 119 = 47.6$		$47.6 \div 1 = 47.6$
Fuel price ($/gal)	$price$	Cost per MegaJoule ($/MJ)	$cost = (price \times gallons) \div MJ$	Daily Cost ($)	$daily = fuel \times cost$
	4.25		$(4.25 \times 0.40) \div 47.6 = 0.036$		$47.6 \times 0.036 = 1.70$

18. Does your car get better gas mileage in the summer or in the winter? Why?

19. Do your driving patterns change seasonally? Are your estimates above representative, or would you need to adjust your numbers up or down to reflect a more accurate annual average?

Direct Use: Food

We've already given some though to our food intake, but let's try to be a little more precise in estimating how much we are paying for the calories we ingest.

Let's not get hung up on nutrition specifics; we all know that if we spend $2.50 on broccoli, we're getting better nutrition than if we spend $2.50 on pretzels. But which $2.50 bought more energy?

You can buy a 10.8oz package of Birds Eye Steamfresh Broccoli Florets, and if you eat the entire bag you will only consume 105kCal. Or you can buy a 16oz bag of Great Value Pretzel Mini Twists! You almost certainly wouldn't eat an entire pound of pretzels all at once, but that bag contains 1800kCal. From a strictly caloric standpoint, the pretzels provide a lot more energy than the broccoli for the same amount of money.

Don't forget to convert your kCal to Joules:

$$1\text{kCal}\left(\frac{4184\text{Joule}}{1\text{kCal}}\right) = 4184\text{J}$$

Age (Years)	Gender	Sedentary (Not Active)	Moderately Active	Active
2-3	Male or female	1,000	1,000	1,000
4-8	Male	1,200 – 1,400	1,400 – 1,600	1,600 – 2,000
	Female	1,200 – 1,400	1,400 – 1,600	1,400 – 1,800
9-13	Male	1,600 – 2,000	1,800 – 2,200	2,000 – 2,600
	Female	1,400 – 1,600	1,600 – 2,000	1,800 – 2,200
14-18	Male	2,000 – 2,400	2,400 – 2,800	2,800 – 3,200
	Female	1,800	2,000	2,400
19-30	Male	2,400 – 2,600	2,600 – 2,800	3,000
	Female	1,800 – 2,000	2,000 – 2,200	2,400
31-50	Male	2,200 – 2,400	2,400 – 2,600	2,800 – 3,000
	Female	1,800	2,000	2,200
51 and older	Male	2,000 – 2,200	2,200 – 2,400	2,400 – 2,800
	Female	1,600	1,800	2,000 – 2,200

Adapted from US Department of Agriculture and US Department of Health and Human Services. *Dietary Guidelines for Americans, 2010.* 7th ed. Washington, DC US Government Printing Office 2010. Http://www.health.gov/dietaryguidelines/2010.asp. Accessed March 18, 2014

When you grocery shop, you buy a variety of items (and everybody likes different foods). So ignore the details of your shopping list, and focus for now on the total expense.

20. Assemble as many receipts as you can: grocery stores, restaurants, convenience stores, wherever you happen to purchase meals or snacks. You want to be able to get as accurate a total as possible for the amount you pay for food each month.

21. Use the chart to assess your calorie needs, and go ahead and assume that you are eating just what you need each day (calorie-wise; you are not gaining or losing weight).

Your Daily Calories	$calories$	Daily Consumption (MJ)	$MJ = joules \div 1 \times 10^6$	Daily Cost of Food ($)	$daily = food \div 30$
	2000		$8.37 \times 10^6 \div 1 \times 10^6 = 8.37$		$300 \div 30 = 10$
Your Daily Energy (J)	$joules = calories \times 4184$	Monthly Food Expenditure ($/month)	$food$	Cost Per MegaJoule ($/MJ)	$cost = daily \div MJ$
	$2000 \times 4184 = 8.37 \times 10^6$		$300		$10 \div 8.37 = 1.20$

Use the example provided in the table above to calculate your own daily use and cost for food. Follow the formulas carefully!

22. Do you spend more for your food energy than you need to? How could you get more energy for less money?

23. When you buy food, do you buy energy–dense items? Is a food item that contains many calories (hence lots of energy) always a better choice than an item with fewer calories? Is a nutrient–dense food item always calorie–dense? What's an example of an energy–dense but nutrient–poor food item that you particularly enjoy?

Indirect Energy Use

Earlier, we started thinking about indirect energy use in the context of a restaurant meal. You've already spent some time considering the energy that went into producing that delicious plate of tacos, so let's take a look at a completely different example.

Consider a plain white cotton t–shirt. You can get one anywhere for about $10, maybe even less. How much energy are you consuming by purchasing and wearing the shirt? Start with the obvious direct use:

- Gasoline to drive to the store
- Electricity to run the washing machine
- Natural gas to run the dryer.

Ok, we've done those, and you have already accounted for them in your monthly averages.

But is that all? How much energy did it take to grow the cotton? Harvest it? Spin it into yarn, weave it into fabric, sew it into a shirt, pack it in a plastic bag, box it up with thousands of others, load it onto a truck, drive it to the port (so far everything we have done to the shirt has happened over in China; you can't get a $10 shirt that was made in America), load it into the cargo container, ship it across the ocean, unload it and truck it to the Target, where you have been waiting all this time to buy it. How much energy did *that* take?

24. Make a list: where and how are you an indirect consumer of energy? Is this easier to do now than it was at the start of the case?

25. The average American consumes approximately 500MJ of energy indirectly each day. Total up your direct daily consumption from the previous sections: natural gas, electricity, gasoline, and food. Summarize your energy profile in a neat table:

Source	Your Daily Use (MJ)	Cost Per MJ ($)	Your Daily Cost ($)
Electricity	153	0.025	$153 \times 0.025 = 3.82$
Natural Gas	97	0.016	$97 \times 0.016 = 1.55$
Gasoline	47.6	0.036	$47.6 \times 0.036 = 1.70$
Food	8.37	1.20	$8.37 \times 1.20 = 10.00$
Total	use = total this column	$\$/MJ = cost \div use$	$cost$ = total this column
	$153 + 97 + 47.6 + 8.37 = 306$	$17.07 \div 306 = 0.056$	$3.82 + 1.55 + 1.70 + 10.00 = 17.07$

26. Compare your direct with your indirect consumption. Do you need to go back to and add more indirect uses to your list?

27. What is your most expensive source of energy on a cost per MJ basis? (It might not be the same as my example!)

28. Is this the same source that cost you the most money per day in actual dollars? Does this surprise you?

29. What did you expect to be most expensive on a per MJ basis? What did you expect to cost the most per day in actual dollars?

Put It Together and Hand It In!

This Case Study is due on Friday, 29 March 2024, no later than 6:00PM.

To prepare your case study for evaluation, create a neat, easy-to-follow document that addresses each of the numbered questions completely. Creating a Google doc that can be shared within your group is a great idea for allowing everyone to have access and be able to contribute to the document. Use tables to organize your numeric results!

Please take a few moments before you submit to make sure that your document is neat, complete, and professional. Proofread it for spelling and grammar (then have another person do it again!). Make sure the questions are numbered, any figures or tables are labeled, and that the document is easy to read.

To submit your case, export the document as a pdf. Blackboard does not recognize a Google doc as an allowable file format for submissions. Use the Blackboard assignment to upload your work, and submit only one document for the entire group. Each Case Study is worth 50 points, and all participating group members will receive the same score.

Remember that you are permitted to self-select your groups, and if you find yourself on a team that isn't your best fit, you can choose to work with different people on the subsequent cases. You are not required to work with the same team each time, but once a team is formed, it's for the duration of the Case.

Scoring Rubric

Your Case Study will be evaluated using the following scoring rubric:

QUESTION	CRITERIA	COMMENTS	POINTS POSSIBLE	POINTS EARNED
1	Examples cited are real and relevant		3	
2	Examples cited are real and relevant to the specific situation		3	
3	Example cited is real and relevant		1	
4	Table is complete and calculations are correctly performed		5	
5				
6				
7				
8	Reasoning is well-thought out and fully explained		2	
9	Reasoning is well-thought out and fully explained		2	
10	Examples cited are real and relevant		2	
11	Opinion is clearly explained		1	
12	Opinion is clearly explained		1	
13	Table is complete and calculations are correctly performed		5	
14	Response is justified		2	
15	Reasoning is well-thought out and fully explained		2	
16	Reasoning is well-thought out and fully explained		2	
17	Table is complete and calculations are correctly performed		5	
18	Response makes sense in the context of the question		2	
19	Reasoning is well-thought out and fully explained		2	
20	Table is complete and calculations are correctly performed		5	
21				
22	Opinion is clearly explained		1	
23	Opinion is clearly explained		1	
24	Response is justified		2	
25	Table is complete and calculations are correctly performed		4	
26	Response makes sense in the context of the question		2	
27	Response is justified by previous calculations		2	
28	Response is justified by previous calculations		2	
29	Opinion is clearly explained		1	

Yes, this adds up to more than 50 points. There are ten bonus points here! Grab them while you can!