**Problem Set 2: Personal Energy Audit**

Please read through all of this problem set before you start collecting data, so that you have an understanding of how the data will be used. It may be helpful to refer to the American Physical Society’s reference page on energy units (<http://www.aps.org/policy/reports/popa-reports/energy/units.cfm>).

You are welcome to (and encouraged to!) collaborate on the problem set. You can also use any resources available to you. Scientists collaborate with each other all the time; they just cite each other to avoid “stealing” ideas. Therefore, I ask that you **explicitly cite** any ideas or hints you get from other people, books, the Internet, or other resources, in your homework. Failure to cite any ideas or hints is plagiarism and will result in a failing grade on the assignment.

This assignment is due at 11:59pm on Sunday, November 2. Late assignments will be docked one letter grade for every day late. Assignments will not be accepted after Wednesday, November 5.

**Part I - Data Collection**

In this exercise, you’ll be our evaluating at your personal energy consumption. Please collect data over **two weekdays** **and the weekend**; from these data, you’ll be extrapolating to your average weekly and annual energy consumption.

You’ll be collecting data regarding your energy consumption in six areas:

* Transportation
* Heating and cooling
* Lighting
* Electronics and appliances
* Food
* Manufactured goods

In addition, we’ll estimate your energy consumption through annual expenditures on services as well.

Please keep track of your data in a spreadsheet program such as Excel. I won’t be collecting your data directly, but you’ll be entering it, sometimes directly and sometimes with some analysis, into your work as you do part 2.

**1. Transportation**

For the four-day data collection period, record the number of commuting miles driven or ridden in a car, bus, train, or airplane. Record each trip separately. For trips in cars, record the type of car and the number of passengers in the vehicle. Also record the miles per gallon for each car; if you do not know this, you can find typical values at

**Example**

|  |  |  |  |
| --- | --- | --- | --- |
| Sat. | New Brunswick to Wegman’s and back | Car (Civic), solo | 24 miles |
|  | Train to New York and back | Train | 75 miles |
| Sun. | To friend’s house and back | Car (Civic), solo | 5 miles |
| Mon. | Cook Campus to Busch Campus and back | Car (Civic), 2 people | 11 miles |
| Tue. | Cook Campus to Busch Campus and back | Car (Civic), solo | 11 miles |

*Honda Civic: 34 miles per gallon*

Separately, estimate the number of long-distance miles you’ve travelled in the last year by each mode of transportation for reasons other than commuting (in order to capture annual transportation use that occurs on a less than weekly basis).

**Example**

|  |  |  |
| --- | --- | --- |
| Road trip | Car (Civic), 2 people | 3,000 miles |
| Amtrak (NE Corridor) | Train | 1,000 miles |
| Airplane | Airplane | 15,000 miles |

 **2. Heating and Cooling**

Hot Water

Record the amount of hot water you use in any of the following ways.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Weekend | Weekday |  |
|  | Sat. | Sun. | Day 1 | Day 2 | Rest of Week |
| Hot shower (length in minutes) |  |  |  |  | - |
| Baths (each) |  |  |  |  | - |
| Dishwasher (number of loads) |  |  |  |  | - |
| Sink (time in minutes) |  |  |  |  | - |
| Laundry, hot (num. of loads) |  |  |  |  |  |
| Laundry, warm (num. of loads) |  |  |  |  |  |
| Other (describe) |  |  |  |  | - |

Since you probably do laundry on a weekly basis, for laundry estimate the number of loads for the remainder of the week outside the data collection window. (If you do laundry less than weekly, estimate an average weekly rate.)

Air Heating and Cooling

If you used heating or air-conditioning at home, for each day, record the outside high and low temperature and the temperature set on the thermostat.

**Example**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Sat | Sun | Mon | Tue |
| High temperature | 48 F | 46 F | 43 F | 45 F |
| Low temperature | 28 F | 32 F | 27 F | 25 F |
| Thermostat temperature | 68 F | 68 F | 68 F | 68 F |

**3. Lighting**

For lighting, record the number of lights on times the amount of time in hours that they are operating. For example, if you had three bulbs on for two hours, record that as “6 bulb hours.”

|  |  |  |
| --- | --- | --- |
|  | Weekend | Weekday |
|  | Sat. | Sun. | Day 3 | Day 4 |
| Incandescent lights |  |  |  |  |
| CFLs |  |  |  |  |
| Fluorescent tube lights |  |  |  |  |
| Other (Describe) |  |  |  |  |

**4. Electronics and Appliances**

Record the amount of time in hours that any of the following appliances are operating. For a desktop computer or a television, please note the nature (LCD/plasma) and size of the display.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Weekend | Weekday |  |
|  | Sat. | Sun. | Day 3 | Day 4 | Rest of Week |
| Refrigerator (large) |  |  |  |  | - |
| Refrigerator (medium dorm size) |  |  |  |  | - |
| Refrigerator (small dorm size) |  |  |  |  | - |
| Washing machine |  |  |  |  |  |
| Clothes dryer (hot) |  |  |  |  |  |
| Clothes dryer (warm) |  |  |  |  |  |
| Hair dryer |  |  |  |  | - |
| Microwave oven |  |  |  |  | - |
| Fan |  |  |  |  | - |
| Computer (desktop, not incl. display) |  |  |  |  | - |
| Computer (laptop) |  |  |  |  | - |
| Phone/camera/e-reader charger |  |  |  |  | - |
| Clock |  |  |  |  | - |
| Television/Computer Monitor |  |  |  |  | - |
| TV Set-Top Box (DVR, DVD, etc.) |  |  |  |  | - |
| Stereo |  |  |  |  | - |
| Other (Describe) |  |  |  |  | - |

Since you probably do laundry on a weekly basis, for laundry estimate the number of hours for the remainder of the week outside the collection window. (If you do laundry less than weekly, estimate an average weekly rate.)

Note that refrigerators typically have a duty cycle of about 30%, which means that 30% of the time they’re on, they are actively drawing energy. You should adjust you estimate of the time the refrigerator is on accordingly.

**5. Food**

For 2 days, record everything you eat and drink, except for water. If you happen to know the number of food Calories in an item, record that as well. (Otherwise, you’ll have to look it up later.)

**Example**

|  |  |  |
| --- | --- | --- |
| Mon.  | Breakfast | Cereal with milk, banana  |
|   | Break | Orange |
|   | Lunch | Salad, hummus sandwich |
|   | Break | Apple |
|   | Dinner | Chicken with pasta |
|   | Break | Ice cream |

**6. Manufactured Goods**

Much of the energy used during industrial processes is reflected in the products we buy. For the four-day data collection period, record everything you buy, except food (which you will record separately). Include subscriptions to newspapers and magazines on a per-issue basis.

**Example**

|  |  |  |
| --- | --- | --- |
| Sat. | Shoes ($50), Tylenol ($10), Paper Towels ($3) |  |
| Sun. | CD ($8) |  |
| Mon. | Pens ($3) |  |
| Tue. | nothing |  |

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**Part II – Data Analysis**

In the following, we will do a number of calculations based on your data to estimate your energy consumption over two weekdays and your energy consumption per weekend. We will then estimate your weekly energy consumption by multiplying your 2-weekday consumption by 5/2 and adding it to your weekend consumption. We will finally multiply this by 52 weeks/year to estimate your annual consumptions.

We will make use of many of the conversion factors you calculated in the class exercise.

I strongly encourage you to make use of a spreadsheet for doing the exercises in this section. Regardless of whether you do the calculations by hand or with a spreadsheet, please show your work. In a spreadsheet, this means that the formulae should be written out visibly, not simply implemented, hidden, in a single cell. You should also use only an appropriate number of significant figures for each answer. (Please, no answers with 5+ sig figs!) I have uploaded my spreadsheet as an example to Sakai.

Please highlight your final answers to each question.

**1. Transportation**

1. **Automobile Travel**

Considering your automobile travel:

1. Calculate how many gallons of gasoline you used per passenger for each trip.
2. Convert this figure to liters.
3. Add up all your weekday travel and your weekend travel to get your gasoline consumption per two weekdays and your gasoline consumption per weekend.
4. Assuming your travel during the data collection period was representative, what is your gasoline consumption during a typical week?
5. Adding in any road trips or other infrequent travel, what is your gasoline consumption during a typical year?
6. Calculate your energy consumption (in kWh) and CO2 emissions (in kg CO2) from automobile travel in a typical week and a typical year.

**b) Bus travel**

Now consider your own bus travel.

1. Estimate your fuel consumption (in liters) from bus travel during the data collection period.
2. Extrapolate to a typical week and to the year, adding in infrequent travel.
3. Calculate your energy consumption (in kWh) and CO2 emissions (in kg CO2) from bus travel in a typical week and a typical year.

**c) Train travel**

Now consider your own train travel.

1. Estimate your fuel consumption (in liters) from train travel during the data collection period.
2. Extrapolate to a typical week and to the year, adding in infrequent travel.
3. Calculate your energy consumption (in kWh) and CO2 emissions (in kg CO2) from train travel in a typical week and a typical year.

**d) Air Travel**

Now consider your own air travel.

1. Estimate how many miles you’ve traveled by air in the past year.
2. Assuming the planes you traveled on were comparable to a Boeing 747-200 at 80% capacity, how many liters of jet fuel did you use in the last year?
3. Calculate your energy consumption and CO2 emissions from air travel in the last year.

**e) Total Liquid Fuels Consumption**

1. Considering all forms of transport, how many liters of fuel did you consume over the past year?
2. What was the associated energy consumption?
3. What were the associated CO2 emissions?

**2. Heating and Cooling**

1. **Hot Water**

Typical flow rates for different uses of hot water are:

* Hot shower: 11 liters/minute
* Baths: 110 liters each
* Dishwasher: 45 liters/load
* Sink: 8 liters/minute
* Laundry, hot: 80 liters/load
* Laundry, warm: 40 liters/load
1. Extrapolate your weekly usage of each demand type, in the units of the data collected (minutes of showers, number of baths, dishwasher loads, etc.), remembering to take into account loads of laundry not captured in the sample period.
2. Calculate your weekly hot water usage.
3. Extrapolate your annual hot water usage.
4. Calculate your annual energy consumption for hot water.
5. Calculate the mass of methane consumed to provide hot water during a year.
6. Calculate the associated CO2 emissions released when methane is combusted to produced CO2 and H2O.
7. **Hot air**

As mentioned previously, there are typically about 5300 heating degree days (in °F below 65°F) in New Brunswick per year.

Assume that the heat is on for 180 days/year.

1. How big (per person) is your room or apartment?
2. What temperature do you keep your thermostat set at when the heat is on? (If you don’t have a thermostat, assume facilities keeps it set for you at 65°F.)
3. If you’re thermostat isn’t kept at 65°F, how many degree days per year do you heat your apartment?
4. What are these equivalent to if you use °C instead of °F?
5. What is your annual energy consumption for hot air?
6. Assuming your furnace is powered by natural gas, what are the associated carbon emissions?
7. **Cold Air**

As mentioned previously, there are typically ~950 cooling degree days (in °F about 65°F) per year in New Brunswick. Assume the A/C is on for about 100 days/year.

1. Do you have central A/C or a window A/C?
2. Calculate the electrical power used to cool your living space. If you have a window A/C, use its power rating (e.g., 5,000 BTU/h) and energy efficiency ratio (e.g, SEER 9 BTU/Wh) to calculate the wattage of the unit. If you have central A/C, assume you have 12,000 BTU/h for every 400 ft2 (37 m2) of living space. If you don’t know the SEER rating of your central A/C , assume it is SEER 13 BTU/Wh. Your final answer should have units of Watts.
3. What temperature do you keep your thermostat set at when the A/C is on? (If you don’t have a thermostat, assume facilities keeps it set for you at 75°F.)
4. If you’re thermostat isn’t kept at 75°F, how many degree days per year do you cool your apartment?
5. Recalling that we assumed 24 hours of A/C operation per 20 degree days, how many hours is your A/C operated per year?
6. What is your annual electricity demand for A/C?

**3. Lighting**

1. Extrapolate from your sample data to calculate the number of bulb-hours you use each type of bulb during a typical week.
2. Calculate your electricity consumption for lighting during the typical week.
3. Extrapolate to the typical year.

**4A. Electronics and Appliances**

Typical wattages for electronics and appliances ate listed below. Some additional values are provided by MacKay. You can use these wattages, or identify the wattages for the actual equipment your using.

There are two ways to do this: for some products, you could look up power on the Internet; for Energy Star labeled products, the Energy Star website (energystar.gov) is a helpful resource; for products that meet California minimum standards, you can also look at the California Energy Commission database (<http://www.appliances.energy.ca.gov/>).

Alternatively, look on the back or bottom of the item, and it usually is written there. If it does not indicate the wattage, then look for the amperage (A).

1. Extrapolate from your sample data to calculate the number of hours you use each type of electronics/appliance during a typical week.
2. Calculate your electricity consumption for electronics/appliances during the typical week.
3. Extrapolate to the typical year.

|  |  |
| --- | --- |
|  | Watts |
| Refrigerator (large) | 750 |
| Refrigerator (medium dorm size) | 330 |
| Refrigerator (small dorm size) | 300 |
| Washing machine | 375 |
| Clothes dryer (hot) | 5,000 |
| Clothes dryer (warm) | 2,500 |
| Hair dryer | 1,875 |
| Microwave oven | 1,450 |
| Fan | 50 |
| Computer (desktop, not incl. display) | 100 |
| Computer (laptop) | 85 |
| Phone/camera/e-reader charger | 7 |
| Clock | 4 |
| LCD Television/Display (19”) | 30 |
| LCD Television/Display (27”) | 60 |
| LCD Television (40”) | 100 |
| LCD Television (55”) | 150 |
| Plasma Television (65”) | 250 |
| Set-Top Box (DVR, DVD, etc.) | 15 |
| Stereo | 100 |

**4B. Total Electricity Consumption**

1. Add up your estimated annual electricity demand from air conditioning, lighting, electronics, and appliances.
2. About 93% of the electricity generated at a power plant makes it to the consumer; about 7% is lost in transmission and distribution. Taken into account transmission and distribution losses, how much electricity must be generated at the power plant to fulfill this demand?
3. Calculate your annual CO2 emissions from electricity.
4. Calculate the primary energy consumption associated with your electrical energy use.

**5. Food**

1. Using the table from Eshel & Martin (2006) and an online calorie calculator (e.g., <http://www.webmd.com/diet/healthtool-food-calorie-counter>) estimate your caloric intake from these different sources. For foods not listed, classify them as a kindred food type: for herbivorous fish, use herring; for carnivorous fish, use salmon; for shellfish, use shrimp; for grains, use corn; for fruits and vegetables, use potatoes; for legumes, use soy.
2. Use the Eshel & Martin efficiency estimates to estimate the amount of fossil energy underlying your diet in the two days your recorded. (Remember that 1,000 food Calorie = 4.184 MJ = 1.2 kWh). For example, 200 food Calories from chicken (efficiency of 18.1%) require input of 1,100 kcal (1,320 kWh) of fossil energy.
3. Extrapolate to your annual fossil energy consumption in food.
4. About 40% of food in the United States is lost as food waste, so increase your consumption accordingly to account for this 60% efficiency. Increase your totals by another 10% to account for energy used for transportation and packaging. What is your revised total fossil energy consumption in food?
5. Assuming a carbon intensity similar to that of liquid fuels for transportation (~0.2 kg CO2/kWh), estimate your associated CO2 emissions.

**6. Manufactured goods**

1. Break down the products you’ve purchased into the following five categories identified in part I and tabulate the amount of money spent in each. (Note that for a product such as a book, the vast majority of the expenditure goes to the intellectual property, not the physical book; this should therefore be counted under services, not manufactured goods.)
* Electronics, appliances, and apparel (0.1 kWh/dollar)
* Wood and metal products (1.1 kWh/dollar)
* Plastic products (0.5 kWh/dollar)
* Paper products (3.9 kWh/dollar)
* Other products (1.0 kWh/dollar)
1. Estimate the total amount you spend in each category per year.
2. Multiply by the energy intensities indicated for each category,.
3. Sum up the energy embodied in products you purchased during a year.
4. Increase your estimates by 10% to account for energy used for transportation and packaging.
5. Assuming a carbon intensity similar to that of liquid fuels for transportation (~0.2 kg CO2/kWh), estimate your associated CO2 emissions.

**7. Services**

1. About how much money did you spend on services in the last year? Include intellectual property such as books, movies, etc. (*Don’t forget that your education is a service, and the money you, your parents and/or the people of the United States spend on your tuition should be counted here! Rutgers in-state tuition is $13,700/year.)*
2. What was the associated energy consumption?
3. What were the associated CO2 emissions?

**8. Summary**

1. Create a summary table tabulating your annual primary energy consumption and associated CO2 emissions from:
* Transportation
* Heating [both air and water]
* Electricity
* Food
* Material consumption
* Services
1. Estimate your total annual primary energy consumption and CO2 emissions.
2. Pretend that your energy consumption was spread evenly over the 8,766 hours of the year. How many watts of power do you use?
3. How do your primary energy consumption and CO2 emissions compare to the world average (21,000 kWh/person/year and 4.9 tonnes CO2/person/year)? How do you compare to the New Jersey average (89,000 kWh/person/year and 14 tonnes CO2/person/year) and the U.S. average (96,000 kWh/person/year and 18,000 tonnes CO2/person/year).
4. The New Jersey and U.S. averages do not account for the energy embodied in goods imported from outside New Jersey or the U.S., respectively. How much of an effect do you expect this to have for NJ? For the US?
5. Brainstorm some ways to discuss your footprint, which we will discuss in class.By examining your current consumption, estimate how much savings you could get from each approach.