Estimating our carbon *FOOD*print **Name(s) ____________________________**

Did you know:

(1) that most food is produced by burning fossil fuels?

(2) That the fossil fuels burned each day to produce an average American's food emit about 12.69 pounds of carbon dioxide into the atmosphere? Over the course of a year, this is about 2.32 tons of carbon dioxide per person. (To put this in perspective, one acre of temperate forest sequesters between 2.45 and 7.35 tons of CO_2 per acre per year.)

This worksheet will investigate how individual dietary choices can affect – and change – our national food-related carbon footprint.





Photos left to right: irrigation system (USDA, 2012), cattle hauling truck (RyanP77, 2013), meat counter at a grocery store (Murtaugh, 2004), refrigerated section of grocery store (Allen, 2005), and a hamburger (Talbert, 2008).

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Part 1: Reflecting on our Diet

The following table lists the major food groups, the emissions intensity of each food group as grams of CO_2 released into the atmosphere per Calorie of the food produced, and the percentage of an average American's diet consisting of each food group.

Food Group	Fruits	Vegetables	Dairy	Red Meat	Poultry	Fish	Eggs	Cereals & Grains	Nuts	Fats, Oils & Sugars
Intensity CO_2 (g/Cal)	1.80	1.03	4.94	9.81	2.70	4.86	3.34	0.89	0.29	0.62
% of daily diet	3.13	4.82	10.57	10.33	6.08	0.55	1.30	23.54	2.76	36.93

Note also that the average American consumes approximately 2,590 Calories of food per day. For comparison, the USDA Estimated Energy Requirements (EER) for a moderately active 16-18 year old female is 2,000 Calories per day; the EER for a moderately active male of the same age is 2,800 Calories.

For Discussion #1: How would you characterize the food groups that have the higher intensity values? Why do you think these food groups might have higher CO_2 values?

For Discussion #2: On a daily basis, the USDA estimates the average daily food availability at 3750 Calories per person. In other words, the food available to people living in the United States averages out to 3750 Calories per person per day. On the other hand, an average American consumes approximately 2,590 Calories of food per day. Discuss the significance of the difference between these two numbers as it relates to the average American's carbon footprint.

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Part 2: Projecting Future National CO_2 Emissions

A **projection** is a mathematically or statistically-determined estimate of some quantity in the future. Projections are used by scientists and policy makers to address questions like "If we assume that …, what can we expect to happen to … in the future?" Determining real world projections frequently requires advanced mathematical knowledge, but not always.

Projections are frequently obtained using a **mathematical model**—a mathematical representation of a real world phenomenon. To create a mathematical model, we start by listing all assumptions that we are going to make. Then, we use these assumptions to determine how to express the phenomenon mathematically. Once we have created the model, we can use it to study the phenomenon.

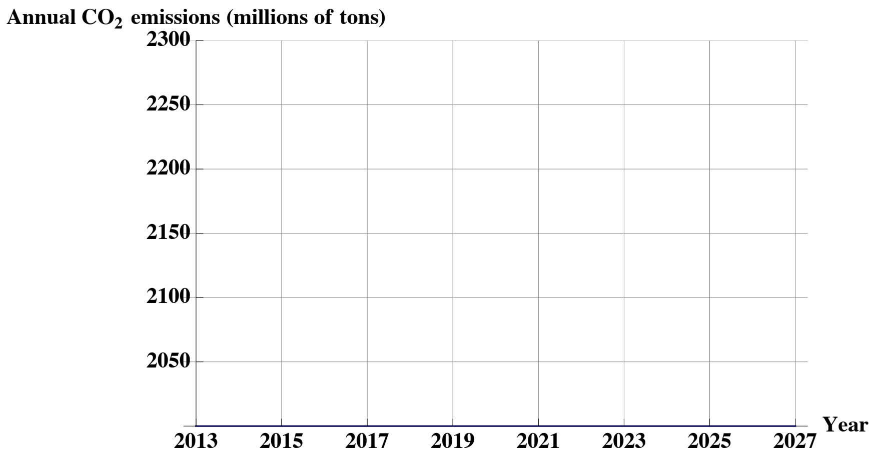
Exercise 1: According to the U.S. Census Bureau, as of January 1, 2015, approximately 320 million people were living in the United States; the population is projected to reach 353 million people by January 2028. If we make two assumptions: (1) that annual population growth will be constant over the years 2015-2028, and (2) that food production and consumption habits will stay the same in future years—so an average of 2.32 tons of CO_2 per person will be emitted each year—we can create a mathematical model to estimate national food-related CO_2 emissions.

a) Estimate total U.S. food-related CO_2 emissions in 2015 and 2028. Give your answer in millions of tons.

b) Calculate the average rate of change in total U.S. food-related CO_2 emissions during the period 2015-2028. Give your answer in millions of tons per year.

c) Assuming constant growth in the U.S. population and each person's emissions are the same each year, what can you say about the growth of the total U.S. food-related emissions each year?

d) On the axes provided below, use your answers to parts (a-c) above to sketch a graph of the total U.S. food-related CO_2 emissions during the period 2015-2028. Draw as carefully as you can.



e) What kind of mathematical equation (function) describes the growth in national CO_2 emissions over time? (For example, linear, quadratic, exponential, logarithmic, …) Explain how you know.

f) Create an equation (a model) that describes the growth in national CO_2 emissions over time. (You drew a graph of this equation in part (d)!) Note: your equation should have

- time (in years since 2015) as the input variable
  - ❖ In other words, year 0 in the model refers to 2015.
- national CO_2 emissions (in millions of tons) as the output variable

g) What are the projected total CO_2 emissions in the year 2020 according to your model in part (f)?

h) According to your model, in what year will the total CO_2 emissions be 15% larger than the 2015 level?

For Discussion #3: What assumptions underlie your answers in Exercise 1 parts (g) and (h)? How would altering your assumptions impact your answers?

For Discussion #4: In Exercise 1, we made two assumptions: (1) that annual population growth will be constant in future years, and (2) that food production and consumption habits will stay the same in future years, so that an average of 6.48 tons of CO_2 will be emitted each year per person. This led to an overall increase in total food-related CO_2 emissions over time. To address this problem, suppose that the U.S. makes a focused effort in 2013 to freeze total food-related CO_2 emissions at the 2013 level. For this effort to succeed, what will have to happen to each person's carbon emissions over time? In other words, can 6.48 tons of CO_2 per person continue to be emitted? Discuss possible ways to change a person's food-related carbon footprint. You can refer back to Part 1 of this activity to inform your discussion.

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Part 3: Freezing Total Food-Related CO_2 Emissions

Exercise 2: In this exercise, we'll create a mathematical model to explore how a person's daily caloric consumption would need to change over time in order for the U.S. to freeze its food-related carbon footprint at the 2015 level. Recall, again, that the population of the U.S. in 2015 was approximately 320 million people. We make the following assumptions: (1) that annual population growth will be constant during the years 2015-2028, reaching 353 million in 2028, and (2) that food production methods and the percentage of food groups eaten daily stay the same.

a) Suppose that the letter T represents the total Calories consumed daily (by the entire country), P represents the size of the U.S. population, and C represents the average number of Calories consumed daily per person. Write down an equation that calculates C in terms of T and P.

b) What is the projected average annual rate of change of the U.S. population over the period 2015-2028? Give your answer in millions of people per year.

c) What kind of mathematical equation (function) describes the growth of the U.S. population over the period 2015-2028? (For example, linear, quadratic, exponential, logarithmic, …) Explain how you know.

d) Create an equation (another model) that describes the growth of the U.S. population over time; in particular it will have
- time (in years since 2015) as the input variable, and
- P, the size of the population (in millions of people), as the output variable

e) Recall that, in 2015, the average American consumed 2590 Calories daily. Estimate T, the total number of Calories consumed daily in the year 2013 (not per person, but rather for the entire country). Give T in millions of Calories. If the U.S. is going to freeze national food-related CO_2 emissions at the 2015 level, then the U.S. is effectively freezing the total number of Calories consumed daily at the 2015 level also.

f) Using your work in parts (a, d, e), create an equation (yet another model!) that describes the average person's daily Calories over time; in particular it will have

- time (in years since 2015) as the input variable, and
- C (daily Calories/person) as the output variable

Note: $\frac{millions\ of\ Calories}{millions\ of\ people} = \frac{10^6\ Calories}{10^6\ people} = \frac{Calories}{person}$

g) Use your model to answer the questions below. In some cases, you will have to solve an equation. In this case, write down the equation and your solution. Remember to give units!!! (Hint: Each equation involves a fraction. To solve, multiply both sides of the equation by the denominator of the fraction. You should then have a linear equation!)

i. In what year is daily consumption of the average American projected to be 2,300 Calories?

ii. How many Calories is the average American projected to consume in 2040?

iii. In what year is daily consumption of the average American projected to be 2,100 Calories?

For Discussion #5: Go back and recall the assumptions that were made in Exercise 2. In light of these assumptions, discuss the reliability of the projections you obtained in part (g).

For Discussion #6: Is it possible to freeze or lower national CO_2 emissions in the future by simply reducing our individual Caloric intake?

For Discussion #7: Would it be possible to freeze or lower national CO_2 emissions in the future by altering our food choices instead of our daily Caloric intake?

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Photos Used in This Activity

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