Energy Units
The purpose of these problems is to begin to get comfortable with the wide array of energy units used, and to gain experience in both doing calculations and in finding other information you need by hunting around. Show your work and the canceling of units for complete credit. All necessary conversion factors are listed in the reading assignment linked in the syllabus. Websites for any other information you may need are provided.

1. BACKGROUND SURVEY:
We would like to learn about your background before coming to this class [Total points: 10]

2. ENERGY USE IN CHINA:
In 2012, China’s electric power sector generated 4,490 billion kWh of electricity (EIA, 2013). For the problems below, assume that 30% of the energy available in the following fuels can be converted to provide for this amount of electricity, unless otherwise indicated. [total points: 30]

   a. How many joules is this equivalent to? Express your answer in TJ. (2 points)
   b. How many kilograms of coal would be required to produce this much electricity? (3 points)
   c. How many kilograms of nuclear fuel? (The fuel fed into a Pebble Bed Modular reactor contains 270,000 MWd [Mega-Watt-day] of energy per metric ton. The efficiency of such a reactor is 35%). (3 points)
   d. How many barrel of oil? (3 points)
   e. How many kilograms of wood? (3 points)
   f. How many cubic feet of natural gas? (Note the temperature and pressure, if known.) (3 points)
   g. How many square meters of solar panels (assume that the panels are placed in the Southwest in an area with an annual average solar radiation of 5.7 kWh/m²/day, and that the solar panels have a conversion efficiency of 14%) (3 points)
   h. How many gallons of water that fall the height of Three Gorge Dam (assume that 1 kg of water at a height of 1 meter stores 10 J of energy)? (3 points)
   i. Calculate the energy density of each of the above fuels in MJ/kg (excluding solar!), and rank them from most to the least energy dense. [Hint: You will need to know the density of oil and natural gas to rank all fuels]. (7 points)

3. TRANSPORTATION OPTIONS [total points: 35 undergraduate/40 graduate]

   a. Imagine Dan Kammen’s neighbor just bought a new 2014 Ford Explorer hybrid SUV (yes, it’s possible even in Berkeley and at least he got the hybrid version) that gets 20 miles to the gallon in city traffic, and around 25 miles to the gallon on the highway. Gasoline costs $4.00/gallon. Dan’s hybrid Honda Civic consumes approximately 4.5 liters gasoline per 100 kilometers driven, both in the city and on the highway. Assuming both the neighbor and Dan drive 13,000 miles per year and drive 60% of their miles on the highway and 40% in the city, calculate average daily gas consumption in gallons per person, and yearly gas expenditure in $ per person. How
much more efficient is Dan’s car and how much money is he saving a year by not driving an SUV? (15 points)

b. California has a plan to introduce 1 million electric vehicles (EVs) by 2020. Assume that the average efficiency of those vehicles is 5 mi/kWh and that they substitute for 1 million conventional cars with an average fuel economy of 30 mpg.
   1. How many gallons of gas a year will be saved in 2020 on account of the substitution of these EVs? (5 points)
   2. What size power plant (in MW) would be required to generate the additional electricity consumed by these vehicles? Assume this power plant has a capacity factor of 0.80. (5 points)
   3. [For ER200/PP284 students only] Why might this million-EV strategy be a climate policy better suited for California than for West Virginia? (5 points)

c. An iconic t-shirt shows a picture of a bicycle and the words “40 miles per burrito”.
   1. Find out how many calories are in a Chipotle chicken burrito (flour tortilla, white rice, black beans, tomato salsa, cheese, lettuce). Assuming the human body can turn 25% of food energy into useful energy for pedaling a bike, what is the equivalent gasoline-based mileage of a bicycle for “40 miles per burrito”? (i.e. miles per gallon of gasoline equivalent) (5 points)
   2. Explain why this answer may be deceiving and over-estimating the energy required to ride a bicycle. (5 points)

4. INTERNATIONAL ENERGY COMPARISONS
   For this problem, please refer to the Energy Information Administration website for all energy data. Please report your answers with no more than three significant digits (or fewer, as appropriate). [total points: 30]

a. Of total global primary energy consumption in 2011, what percent did the U.S. consume? (3 points)

b. What is the average per capita consumption (in Btu/person) for the U.S. for 2011? For the world? For China? Cameroon? Spain? Qatar? Thailand? Egypt? Pakistan? (Hint: you need to find GDP and population data – you may want to use the CIA World Factbook: https://www.cia.gov/library/publications/the-world-factbook/.) Use the most recent data available, and indicate what year(s) you used. (3 points)

c. Looking at the per capita energy use of the countries listed above, what is the ratio between the country with the largest and the country with the smallest rates of per capita consumption? What are those countries? (4 points)
d. Compare energy use per capita for three of these countries in two years, 2008 and another at least 20 years earlier. How do these trajectories differ? What might explain this? Be sure to indicate the countries and years that you are comparing (10 points)

e. [For ER100/PP184 students only] Using data for the countries listed in part b, examine the relationship between per capita energy use and GDP per capita. Draw a graph of those two statistics for those countries. Can you suggest anything about the correlation between per capita energy consumption and per capita income. For this graph, should energy consumption per capita be on x-axis or the y-axis? (10 points)

f. [For ER200/PP284 students only] The energy intensity of a country’s economy is defined as the ratio of its total primary energy consumption to its GDP for a given year. What might be the advantages of using energy intensity as a unit of analysis as compared to using energy use per capita? What might we infer about a country whose energy intensity has been decreasing over time? What factors might cause energy intensity to differ between two industrialized nations (for example, the United States and Germany)? (10 points)

5. ART ROSENFELD is a living legend in the energy field. Through a career that has seen him as a professor at UC Berkeley, a researcher at Lawrence Berkeley National Labs, and a commissioner of the California Energy Commission, Dr. Rosenfeld has for the past 35 years been a worldwide leader in the promotion of energy efficiency. In 2010, it was proposed that a new unit, the Rosenfeld, be created in his honor. The Rosenfeld would be a measure of energy savings (i.e., electricity that doesn’t need to be generated because demand has been decreased through conservation or the use of energy-efficient technologies), with 1 Rosenfeld being equal to the avoided electricity production of a 500 MW coal power plant that is:

1). 35% efficient
2). loses 10% of the electricity produced in transmission and distribution to end-users
3). has a capacity factor of 72%

Using this information, please answer the following questions. [Total points: 25]

a. Based on the numerical parameters in the definition of a Rosenfeld given above, how many significant digits are implied in the use of the Rosenfeld unit? (3 points)

b. What is the equivalent of one Rosenfeld in units of kWh? EJ? (8 points)

c. If enough electricity is saved to avoid burning 500 g of coal, how many Rosenfeld-years of savings does that represent? (7 points)

d. My refrigerator uses a constant 60 W of electricity, but I’m planning on replacing it with a new, more efficient unit. What would the wattage of my replacement fridge have to be in order to see energy savings of 60 nano-Rosenfelds over the course of a year? (7 points)
6. [ER200/PP284, and ‘optional test your skills’ problem for ER100, 184] [Total points: 10]

What is the energy resource available to the Earth from the Sun?

Based on Einstein’s famous equation \( E=mc^2 \) provide a back of the envelope calculation to determine what is the solar radiation available at the edge of the Earth’s atmosphere.

*Do not look up the result, but do the calculation and then check you assumptions based on the published value.*

Use the following information and your knowledge of units.

Parameters of solar (nuclear) fusion:

- The mass of a Hydrogen atom, written \(^1\text{H} = 1.0078\) AMU (atomic mass units)
- The mass of a Helium atom, written \(^4\text{He} = 4.0026\) AMU

The mass of the sum is \(2 \times 10^{30}\) kg

The distance from the Earth to the Sun is 150 million km, \(1.5 \times 10^8\) km

The Sun will become a red giant (changing the amount of energy the Earth receives, because the Earth will be inside the Sun, or more likely, will be destroyed) when 10% of the \(^1\text{H}\) is consumed. This will happen after about \(10^{10}\) years, so we have some time.

a) What is the solar resource available at the edge of the Earth’s atmosphere? (5 points)

b) What is the ‘correct’ value, and offer some thoughts on why you are off (2 sentences, maximum) (5 points)