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Subject: Quantitative Reasoning Data for Environmental Studies Area R courses

We have assessed quantitative reasoning in our two Environmental Studies Area R courses, EnvS 119 - Energy and the Environment, and EnvS 152 - Globalization and the Environment. The courses take two different approaches to assessing quantitative reasoning. In EnvS 119, students must conduct simple calculations, while in EnvS 152 students must evaluate the scientific validity of different arguments. Here are recent results from the two courses.

<u>EnvS 119 - Energy and the Environment</u>

The quantitative assignment used in this assessment familiarizes students with unit conversations and dimensional analysis for common questions important to energy analysis. Students must demonstrate they know the relationship between power and energy, that they can convert between different units, and demonstrate the relationship between energy use and greenhouse gas emissions. The assignment, with answers, is attached. This assignment occurs relatively early in the course.

Grades from the past three semesters for a total of 140 students (table below) showed a very bimodal distribution. Half the students received C's or above and have D's or F's.

	Spring 2013	Fall 2013	Spring 2014	*Total*	Percent
A	6	14	11	*31*	25%
B	8	8	7	*23*	19%
C	2	5	1	*8*	7%
D	5	11	6	*22*	18%
F	6	24	10	*40*	32%
Total	27	62	35	*124*	100%

Over the years, the professor teaching this course, Dr. Mulvaney, has created an assignment that students must complete before this one, which has very simple dimensional analysis and unit conversions. In addition, students must do these same types of calculations for the final exam. Dr. Mulvaney believes students do better on the final exam computations as compared to this one, which occurs much earlier in the semester. In the future, the professor is planning to have an assignment at the end of the course that he can readily compare to this assignment, to determine if students are improving in their ability to conduct these computations. Based on those results, we will determine measures to improve student abilities, as needed.

<u>EnvS 152 - Globalization and the Environment</u>

Students wrote a 750- to 1,250-word essay that identifies the consequences of accepting pseudoscience findings as valid for individuals and for society. The assignment requires students select their own top three criteria for judging whether an argument has scientific merit, is non-scientific, is bad science, or is pseudoscience based on information provided by the professor. The students analyze the scientific validity of assertions made by authors of three different articles on globalization and its social and environmental impacts. They identify evidence used by the authors to support their arguments and to bring in evidence presented in other class readings (e.g., Tom Friedman's *Hot, Flat, and Crowded*).

The table, below, summarizes data for three sections of EnvS 152. Data on 62 students shows that 78% of students earned an A (90-100%) or B (80-89%) on the assignment, 19% earned a C (70-79%), and 3% of students failed the assignment.

	Fall 2012	Fall 2012	Fall 2013	Total	Percent
A	7	6	11	24	39%
B	4	8	12	24	39%
C	6	3	3	12	19%
D	0	0	0	0	0%
F	1	0	1	2	3%
Total	18	17	27	62	100%

The assignment was slightly modified in Fall of 2013 by asking the students to focus on one specific argument made by the authors (e.g., increased levels of economic globalization lead to improvements in environmental quality), rather than examine the article as a whole. The small increase in the percentage of students earning A's and B's--a total of 71% in Fall 2012 compared to 76% in Fall 2013--might be due to the modification of the assignment. But, other factors could easily have contributed to this difference. For example, in Fall 2012, EnvS 152 took place online while the Fall 2013 section was delivered as a hybrid (partially online, partially in-person) course. Overall, students do quite well on this type of assessment of quantitative reasoning.

ENVS 119 Energy and the Environment:

Assignment 2 - Unit conversions and problem sets (KEY)

1. In an article in the *New York Times,* Google announced their power use attributed to Google searches is 12.5 million Watts. (a) How much energy is this per day in kWh? (b) Calculate the carbon emissions related to all Google searches in a day based on the energy use in lbs. CO_2. Assume the electricity is generated in PG&E territory with a 0.524 lbs CO_2e/kWh emissions factor. (c) Assume there are 1 billion searches per day. What is the carbon footprint of an individual Google search? Report your final answer in **grams CO_2e per Google Search**.

$$12{,}500{,}000\ W\ x\ \frac{1\ kW}{1{,}000\ W}\ x\ \frac{24\ h}{d} = 300{,}000\ \frac{kWh}{d}$$ 5 points

300,000 kWh/d x 0.524 lbs CO2/kWh = ~150,000 lbs 5 points

$$300{,}000\frac{kWh}{d}\ x\ \frac{1\ d}{1{,}000{,}000{,}000\ searches}\ x\ \frac{0.524\ lbs}{kWh}\ x\ \frac{453.6\ g}{1\ lbs} = 0.07\ \frac{gCO2e}{Google\ search}$$

2. Human beings are capable of doing approximately 100 Watts of work per person. Diablo Canyon Nuclear Power Plant is capable of 2.35 GW of power. (a) How many human beings (turning a crankshaft) would it take to generate 2.35 GW of power? Assume that 50% of this power is converted to useful energy (meaning the crankshaft is 50% efficient at converting human power into electricity). (b) If these workers were paid $8 per hour, how much would the electricity cost in **$/kWh**? (c) If an average home consumes 500 kWh per month, how much would one month's electricity cost (in **$**)?

$$\frac{1\ person}{100\ W}\ x\ \frac{1W\ in}{0.5\ Wout}\ x\ \frac{2{,}350{,}000{,}000\ W}{Nuclear\ power\ plant} = 47{,}000{,}000\ \frac{person}{Nuclear\ power\ plant}$$ (10 points)

$$2{,}350{,}000\ kW\ x\ \frac{24\ h}{d}\ x\ \frac{30\ d}{month} = \frac{1{,}692{,}000{,}000\ kWh}{month}$$

$$\frac{47{,}000{,}000\ person}{shift}\ x\ \frac{3\ shift}{d}\ x\ \frac{\$8}{person}\ x\ \frac{30\ d}{month} = \frac{\$33{,}840{,}000{,}000}{month}$$

$$\frac{\frac{\$33{,}840{,}000{,}000}{month}}{\frac{1{,}692{,}000{,}000\ kWh}{month}} = \frac{\$20}{kWh}$$ (5 points)

$20/kWh x 500kWh/mo = $1,000 per month (5 points)

3. The Energy Policy Act of 2005 mandates the production of 36 billion gallons of ethanol per year by 2022. (a) How much energy does 36 billions gallons of ethanol contain (in **MJ**)? (b) If US

drivers use the same amount of energy to get around, how many gallons of gasoline would this displace each year?

$36{,}000{,}000{,}000\ gallon\ EtOH\ x\ \frac{80.2\ MJ}{gallon\ EtOH} = 2{,}890{,}000{,}000{,}000\ MJ$ (10 points)

$2{,}890{,}000{,}000{,}000\ MJ\ x\ \frac{gallon\ gasoline}{121.3\ MJ} = 23{,}800{,}000{,}000\ gallons\ gasoline$ (10 points)

4. The US imports 12 million barrels of oil (bbl) per day (hint: note that this is a rate of energy consumption because it is energy per unit time). Each bbl contains 5.8×10^6 BTU of energy, often referred to as a barrel of oil equivalent (boe). (a) Convert the rate of daily oil imports into power (**GW**). (b) If the US wanted to electrify its auto fleet using nuclear power, how many Diablo Canyon nuclear plants worth of power would be needed (each can provide 2.35 GW of power)? (NOTE: EVs are more efficient than ICEs, so the actual number of Diablo Canyon plants would be lower, probably about 1/3 of the number you calculate here).

$$\frac{12{,}000{,}000\ bbl}{d}\ x\ \frac{5{,}800{,}000\ \text{BTU}}{1\ bbl}\ x\ \frac{1055\ J}{1\ BTU}\ x\ \frac{1\ d}{86{,}400\ s}\ x\ \frac{1\ MW}{1{,}000{,}000\ W}$$

$$(a) = \ 850\ GW$$

(b) divide a by 2.35 GW = 362 power plants

5. Solar energy reaches the surface of Earth at 240 W/m^2 (Watts/square meter). Photovoltaic cells capture energy from the sun and make electricity at around 15% efficiency. Assuming there are 300 million people consuming 10kW per person, roughly how much land is needed to generate all this electricity from solar power in square miles (mi^2)? Would it fit in the Mojave Desert (25,000 mi^2)?

$$\frac{m^2}{240\ W}\ x\ \frac{1\ \text{W}}{0.15\ W}\ x\ \frac{1000\ W}{1\ kW}\ x\ \frac{1\ mi^2}{2.6\ km^2}\ x\ \frac{1\ km^2}{1{,}000{,}000\ m^2}\ x\ \frac{10\ kW}{person}\ x\ 300{,}000{,}000\ person$$

$= \ 32{,}000\ mi^2$