Problem Set 1b—KEY

CEEG 340–Introduction to Environmental Engineering

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August 28, 2017

Questions

- Problems 1(a) and 1(b) are on the next two pages.
- Problem 1(c): LCA is most appropriate for comparing two products or processes. You want to compare the life cycle environmental impacts of the following pairs of products. Choose a functional unit for the LCA models:

  Multiple answers may be correct. The following are options:

  1. steak vs. tofu
     Examples: 1 g of protein, 200 calories
  2. ethanol vs. conventional gasoline (assume that both are used to power automobiles)
     1 MJ of energy, 1 gal of fuel (acceptable but not best answer because ethanol and gasoline have different heating values (i.e., energy contents).
  3. electric powered vehicle vs. gasoline powered vehicle
     1 mile traveled
  4. plastic bag vs. paper bag
     5 kg groceries carried; 1 gal groceries carried
  5. construction project with or without incorporation of LEED certified standards
     1200 sq. feet
  6. tequila vs. beer
     2 oz of alcohol
  7. electric-powered hand dryer vs. paper towels
     1 pair of dried hands, 5 mL of water removed
  8. aerobic vs. anaerobic wastewater treatment
     Treatment of 2 million gallons of wastewater to achieve required effluent standards of 30 mg/L BOD, 30 mg/L TSS)

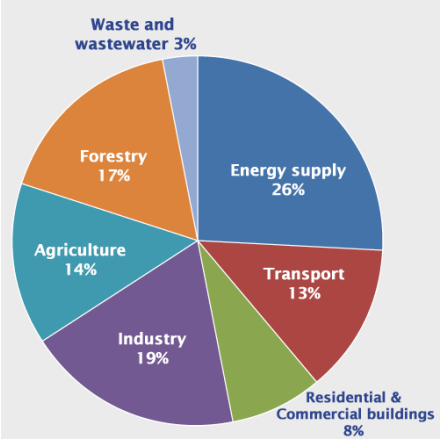
Question #1: Energy

1a. **1.6** Go to the U.S Department of Energy's website (www.doe.gov), and research energy consumption in the household, commercial, industrial, and transportation sectors. Develop a table on how this specific energy consumption relates to the percent of U.S. and global CO_2 emissions. Identify a sustainable solution for each sector that would reduce energy use and CO_2 emissions. 10 pts

Solution:

Students will need to do some research on the web for this item. Energy consumption values can be found on the Annual Energy Review website (http://www.eia.gov/totalenergy/data/annual/index.cfm) . Greenhouse gas emissions by sector can be found on the EPA (http://www.epa.gov/climatechange/ghgemissions/global.html) or IPPC web pages.

Sector	Total U.S. Energy Consumption in 2012 (trillion Btu)	Percent of U.S. Emissions (2012)	Percent Global Emissions (2004)	Sustainable Solution (Students answers may vary)
Household	20,195	21.3%	8% (includes household & commercial	Solar panels
Commercial	17,507	18.4%	(see above)	LED light fixtures
Industrial	30,562	32.2%	19%	Carbon tax
Transportation	26,712	28.1%	13%	Public transportation infrastructure
Total	94,977	100%	See figure below for more details	



Global greenhouse gas emissions by source (commercial and residential are grouped) (EPA reference to IPCC 2007 for global emissions in 2004)

1b. **1.7** As a consumer interested in reducing your carbon emissions, (a) which should you do: (1) install more efficient lighting for your home or (2) buy a car that gets higher miles per gallon? To answer this, consider that a 100W light bulb that is run 3 hours a day every day will use around 100 kWh a year. A high efficiency light uses about 25% of a conventional light bulb. Replacing it with a 25W Compact Fluorescent Bulb would save 75 kWh a year. This would equal 150 lbs of carbon dioxide or the same amount of carbon dioxide emissions associated with burning 7.5 gallons of gasoline. (b) Given that the average US household uses 10,000 kWh a year of which 8.8% is lighting, how many gallons of gas and lbs of CO2 could be saved by switching all of the bulbs in a home? (c) For comparison, if you drove 12,000 miles a year and upgraded from a car that gets the national average of 20 mpg to one that got 30 mpg, how much would you reduce your gas consumption and CO2 emissions on an annual basis? (d) What if you upgraded from a car that gets 30 mpg to 37 mpg? (combustion of 100 gallons of gasoline releases 2,000 lbs. of carbon dioxide).

Solution:

a. You would choose an answer depending on your house, your lighting habits, your type of car and how you use it. You could ask questions like how many light bulbs you use in your home and for how long each day and how much you drive each year. In fact, the average US consumer would save a little more energy and CO2 emissions by upgrading their card. 2.5 pts

b.

2.5 pts

$$10{,}000kWh \times 0.088 \times 0.75 \times \frac{150\ lbs\ CO_2}{75\ kWh} = \mathbf{1{,}320\ lbs\ CO_2\ savings}$$

$$10{,}000kWh \times 0.088 \times 0.75 \times \frac{7.5\ gallons}{75\ kWh} = \mathbf{66\ gallons\ gas\ savings}$$

c.

2.5 pts

$$(12{,}000\ miles \times \tfrac{1\ gallon}{20\ miles}) - (12{,}000\ miles \times \tfrac{1\ gallon}{30\ miles}) = \mathbf{200\ gallons}$$

$$200\ gallons \times \frac{2{,}000\ lbs\ CO_2}{100\ gallons} = \mathbf{4000\ lbs\ CO_2}$$

d. Switching from a 30 mpg vehicle to 37 mpg vehicle results in a 10 mpg savings.

2.5 pts

$$(12{,}000\ miles \times \tfrac{1\ gallon}{30\ miles}) - (12{,}000\ miles \times \tfrac{1\ gallon}{37\ miles}) = \mathbf{76\ gallons}$$

$$76\ gallons \times \tfrac{2{,}000\ lbs\ CO_2}{100\ gallons} = \mathbf{1{,}520\ lbs\ CO_2/yr}$$

1d.

1.10 To compare plastic and paper bags in terms of acquisition of raw materials, manufacturing and processing, use and disposal, we'll use data provided by Franklin Associates, a nationally known consulting firm whose clients include the U.S. Environmental Protection Agency as well as many companies and industry groups. In 1990, Franklin Associates compared plastic bags to paper bags in terms of their energy and air/water emissions in manufacture, use, and disposal. Table 1.9 presents the results of their study:

Table/1.9 Results of Study Comparing Plastic and Paper Bags

Life Cycle Stages	Air Emissions (pollutants) oz/bag		Energy Required BTU/bag	
	Paper	Plastic	Paper	Plastic
Materials manufacture, product manufacture, product use	0.0516	0.0146	905	464
Raw materials acquisition, product disposal	0.0510	0.0045	724	185

(a)Which bag would you choose if you were most concerned about air pollution? (Note that the information does not tell you if these are toxic air emissions or greenhouse gas emissions) (b) If you assume that two plastic bags equal one paper bag, does the choice change? (c) Compare the energy required to produce each bag. Which bag takes less energy to produce?

Solution:

a) For paper: 0.0516 + 0.0510 = 0.1026 oz/bag
For plastic: 0.0146 + 0.0045 = 0.0191 oz/bag 3.3pts

Plastic; however, the nature of the air emissions may be of concern.

b) For paper: 0.0516 + 0.0510 = 0.1026 oz/bag
For plastic: (0.0146 + 0.0045) * 2 = 0.0382 oz/bag 3.3pts

No. Plastic still has a lower life cycle air emissions than paper even with using twice as many bags.

3.3pts

c) For paper = 905 + 724 = 1629 BTU/bag
For plastic = 464 + 185 = 649 BTU/bag

Plastic bags take less energy to produce (even at the 2:1 ratio).

1.11 You are preparing a life cycle analysis of three different electrification options for powering your 1,200 square foot home in rural Connecticut. The options you're considering include: 1) just using your local grid, 2) putting in a solar installation on your roof, or 3) building a transmission extension to join up with your neighbor's already-built wind turbine. Write a possible goal, scope, function, and functional unit for this LCA. Explain your reasoning.

Solution:

Student's answers may vary.

Goal: Determine which of the following electrification options have the least environmental impact: 1) just using your local grid, 2) putting in a solar installation on your roof, or 3) building a transmission extension to join up with your neighbor's already-built wind turbine. 1.25 pts

Scope: This LCA will consider the resource extraction, manufacturing, and use-phase but will not consider transportation and end-of-life stage. 1.25 pts

Function: Provide enough energy to light and run appliances in a 1,200 square foot home in rural Connecticut. 1.25 pts

Functional unit: The energy to power a 1,200 square foot home in rural Connecticut. 1.25 pts

1.12 Consider the full life cycle of each of the three electrification options (possibly beyond whatever you've selected for the scope of your LCA) in Problem 1.11. Discuss which of the life cycle stages is most impactful for each electrification type. You will need to take into account the life cycle impacts of primary through final energy in each case. As a reminder, life cycle stages typically include: resource extraction, manufacture, transportation, use, and end of life.

Solution:

Student responses will vary but below is an example solution. 5 pts

Electrification Option	**Impactful life stage**
1) Just using your local grid	Material extraction of non-renewable resource such as coal and the burning of such during the use-phase.
2) Putting in a solar installation on your roof	Material extraction of metals for solar panels. End-of-use in recycling/disposal of solar panels.
3) Building a transmission extension to join up with your neighbor's already-built wind turbine	Material extraction for materials to build the extension.