Appendix A

Figure 1 presents the graphs showing the average data for (a) withdrawal rate, (b) passing rate and (c) C grade or better for SEGE versus BIO, CHEM, and GIS over three semesters- Sp16, F16, Sp17. Figure 2 presents the comparison among the withdrawal rate, the passing rate, and C grade and better performance in two semesters, Sp16 and Sp17. The data from F17 semester is not included in Figure 1 due to low comparison data.

Course syllabus: Sustainability, Energy, and The Green Economy

PHY/CHEM/BIO 100

|  |  |
| --- | --- |
| **Week 1:** **Introductions and brief history of sustainability** Instructors’ introduction: background, research and teaching interests**,** students’ introduction: background, majors and expectations for course, introduction to course plan, objectives and teaching format. The BIO instructor opened the course with a brief history of Sustainability-The Industrial Revolution**,** Bretton Woods and the rise of Neoliberalism**,** Declaration of the United Nations Conference on the Human Environment**,** The Brundtland Commission – *Our Common Future***,** Sustainable Development, The Earth Charter. | **Team-teaching PHY/CHEM/BIO instructors**Pisani (2006); Theis & Tomkin (2015), Module 1 |
| **Week 2: Mathematical Principals and Introduction to LCA-** The PHY and CHEM instructors reviewed the concepts of measurement and the Scientific Method, Unit Conversion, The Mole Concept, Exponential functions. The BIO instructor connected the mathematical review in the global population growth: exponential growth and its effects, population density, carrying capacity and ecological footprint, coastal population growth: Bangladesh’s population growth and migration in Europe. | **Team-teaching PHY/CHEM/BIO instructors**Theis & Tomkin (2015), Module 9.1 |
| **Week 3: Principles of Sustainability-** The BIO instructor explained the relationship of humans with the environment, levels of life’s organization: atom, molecule, cell, tissue, organ, organ systems, individual, population, community, ecosystem, biosphere, ecological succession (primary and secondary), fermentation, composting, energy flow in ecosystems; from producers to consumers - food chains, food webs, trophic levels, energy mass, ecological pyramid, chemical cycles: water, carbon, nitrogen, and phosphorus. | **BIO instructor**McConnell & Abel (2012), Part 1 |
| **Week 4: Threats on Ecosystems-** The BIO instructor discussed the global grain production and the origin of agriculture, pound for pound the cost of what we eat: a case for vegetarianism, soil and sustainable societies: the nature of the soil, urbanization and soil loss, erosion, desertification and salt build-up, roots and the American Dust Bowl – an agricultural disaster, the state of global forests: types of forests, industrial value versus ecological value, catch of the day: the state of global fisheries, invasive species, hatching schedules, and the food web. | **BIO instructor**McConnell & Abel (2012), Part 6 |
| **Week 5: Carbon and other Raw Materials-** The CHEM instructor discussed the raw materials in mining, processing, and product manufacturing stages of the Life Cycle Analysis (LCA), quantify sustainability in greenhouse gases (GHGs), the carbon footprint calculation, and the stages of LCA. | **CHEM instructor**Theis & Tomkin (2015), Module 9 (9.1, 9.2, 9.3) |
| **Week 6: Climate Change-** The PHY instructorexplained the atmospheric composition, greenhouse gasses and climate change, global warming: atmosphere and ocean interaction, rising sea levels, and precipitation. | **PHY instructor** McConnell & Abel (2012), Part 3; Theis & Tomkin (2015), Chapter 3; Henson (2011); Instructor notes from AMNH Seminars on Science Online Courses for Educators |
| **Week 7: Screening of Media followed by the Discussion-**Guggenheim (Director) (2006). *An inconvenient truth: A global warning* [DVD]. Hollywood: Paramount or Stevens (2016). *Before the Flood* [Video]. United States. | **Team-teaching PHY/CHEM/BIO instructors** |
| **Midterm** | **LCA Research Paper Outline Submission.** |
| **Week 8: Introduction to Energy-** The PHY instructor introduced the relevance of Energy in science, politics and economics, reviewed unit conversions in Energy (Joules, calories and moles), discussed What do we do now: Oil, Coal, Natural Gas, and Nuclear in NYC, nationwide and globally? Available resources, origins of fossil fuels, global distribution, transportation to refineries, peak oil, shale, natural gas, measuring impact: air/water pollution, nuclear waste, mining, carbon capture.  | **PHY instructor** **LCA Research Paper Discussion begins during the postmidterm recitation periods.**McConnell & Abel (2012), Part 4;Theis & Tomkin (2015), Module 8 |
| **Week 9: Introduction to Renewable Energy-** The PHY instructor discussed the Sustainable Energy Sources: Solar, Wind, Hydro, Geothermal, Biomass/Biofuels**,** Enabling Technologies: Hydrofracking, Energy Storage, and Transmission**,** Energy density comparisons: Liquid fuels versus batteries**,** Sunk costs and industrial inertia.  | **PHY instructor** Theis & Tomkin (2015), Module 8; Smith et al. (2016) |
| **Weeks 10: Consumption and the Quality of Life-** The CHEM instructor focused on global water supplies, the hydrologic cycle, worth of water, global distribution, control, and the impact of contamination,Motor Vehicles: driving trends, emissions, fuel economy, and regulation, Turfgrass: Land use changes in North America, the lawn care industry, allergies, gas-powered leaf blowers,Mountains of Trash: Types of waste, transport, landfills, The demand for mineral resources - Mining: methods and impacts,Recycling: from waste to resources,The power of lifestyle choices: What is your footprint?,Sustainable consumption,Health and nutrition,Sustainable population,Development,Economic growth and the environment.  | **CHEM instructor** McConnell & Abel (2012), Part 5 |
| **Week 11: Jobs and the Green Economy-** The CHEM instructor built on Week 9 lecture on introduction to Renewable Energy – Solar, wind, geothermal, marine, Transportation – Automotive, aviation, public transit, alternative fuels, Buildings – LEED, Energy auditor, green/white roofs**;** Analytical and Green Chemistry (engineering, biomass, biofuels, Fermentation, Biology),Resource and Environmental management – DEP, public utilities, waste management, forestry, agriculture, Fish and Wildlife, NGOs, Programs within BCC/CUNY/NYC; BioEnergy jobs/NSF ATE Project/Industrial Advisory Board Members and Companies**;** Green Job Websites + Interview Tips. | **Team-teaching PHY/CHEM/BIO instructors**Theis & Tomkin (2015), Module 11; Ottman (2011); Llewellyn, Hendrix & Golden (2008) |
| **Week 12: Practicing Sustainability in Urban Environments-**The CHEM instructor focused on Sustainable Community Planning: Sprawl versus Smart Growth, Resiliency – building in the face of tropical storms and earthquakes,Sustainable building: LEED,Urban Retrofits – working with what we have: energy audits, ConEd and the Green team,What can you do at home? | **CHEM instructor** McConnell & Abel (2012), Part 7 |
| **Week 13: The Road to Sustainability-** The team discussed the greening of the marketplace – The power of eco-marketing,Sustainable Business practices,Reducing the corporate energy footprint,Sustainable Manufacturing. | **Team-teaching PHY/CHEM/BIO instructors**Theis & Tomkin (2015), Module 9.4 |
| Week 14: **Review Student Presentations** (The team scheduled one on one with students) | **Team-teaching PHY/CHEM/BIO instructors**Gutowski (2014) |

Additional Resources: Newsletters that focus on environmental and sustainability issues:

* <http://3blmedia.com/>
* http://www.theguardian.com/us/environment
* <http://www.csrwire.com/>
* <http://green.blogs.nytimes.com/>
* <http://www.corporateregister.com/>
* <http://www.environmentalleader.com/>
* <http://www.greenbiz.com/>
* <http://grist.org/>
* <http://www.sustainablebrands.com/>
* [www.responsible-investor.com/](http://www.responsible-investor.com/)
* [www.socialfunds.com](http://www.socialfunds.com)
* <http://www.greenerchoices.org/>
* [http://www.goodguide.com/#](http://www.goodguide.com/)
* <http://www.newdream.org/>
* <http://www.treehugger.com/>

Midterm LCA paper

The midterm paper counted as a midterm exam and constituted 10% of the total course grade. Each student was to choose *one* *product* (e.g., an “energy beverage”) and select *two* *brands* of this product to compare and contrast (e.g., Red Bull Energy Drink versus Bigelow green tea). The midterm included a one- or two-page paper outlining the assigned product and the LCA.

Final project and presentation

Sustainability energy and the green economy

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The final project and presentation counted as a final exam and constitute 35% of the total course grade. Students were assigned one product (e.g., an “energy beverage”) and selected two brands of this product to compare and contrast (e.g., Red Bull Energy Drink versus Bigelow green tea). The goal of the LCA project/presentation was to research, validate and convince students (i.e., customers/consumers) about the specific metrics upon which to rank the products in terms of their overall sustainability. Students may interview representatives from the product’s company to find some answers. The following criteria were used for assessment:

1. **History and sourcing of materials** used to make the product (i.e., Where were the product’s components made or grown? On what scale were they produced? How long to produce, and at what cost are they produced?
2. **What is the global market demand** **for the product?** Based on your research, how much is the demand increasing or decreasing? Why?
3. **What is the “Life Cycle Analysis” of the major components of the product?** How much CO2 is released to make the product, and what is the environmental fate of the product?

Appendix B

Sample LCA calculations describing dimensional analysis for quantifying CO2 emissions of a consumer product.

The term *life cycle* refers to the major activities in the course of the product’s lifespan from sourcing raw materials, manufacturing, use, maintenance, and final disposal/recycling. Manufacturers perform LCA to broaden their views and inform consumers of a product’s environmental impact. To perform the simple LCA on a chosen consumer product, boundary conditions of the product are defined, and calculations are performed using physical and thermodynamic data. All calculations can be normalized to a single unit (e.g., CO2 emissions).

**Boundary conditions:** Cooling a 355 mL can of soda for one week and shipping *via* truck from Atlanta, SC to New York, NY.

**Model calculations to calculate the amount of CO2 emissions (lbs) required to cool a can of soda**

1. **CO2 emissions per week to refrigerate a can of soda**

 Cost of refrigeration per day [1]

|  |  |
| --- | --- |
| Hours used per day | 24 |
| Standard refrigerator power use in kW | 0.18 |
|  |
| kWh per day |  |  4.32 |  |

The amount of CO2 emissions by natural gas fuel in 2018 per day is 0.92 lbs per kWh [2]

The amount of CO2 emissions per week to refrigerate a can of soda for one week:

$\frac{4.32 kWh}{1 day} ×\frac{0.92 lbs CO\_{2}}{kWh}×\frac{7 days}{1 week}=27.82 lbs CO\_{2}/week $

Considering the volume of the refrigerator at 1500 liters and the volume of a can of soda at 0.355 liters, the amount of CO2 released per week would be

$0.355 L×\frac{27.82 lbs CO\_{2}/week }{1500 L}=0.0065 lbs CO\_{2}/week$

1. **CO2 emissions per week to transport via truck from Atlanta to NYC**

 $863 miles×\frac{1 gallon}{5.9 miles}×\frac{22.38 lbs CO\_{2}}{1 gallon diesel}=3274 lbs CO\_{2}/week$

Considering the working volume of truck’s trailer at 100,000 liters and the volume of a can of soda at 0.355 liters, the amount of CO2 released per week would be:

$ 0.355 L×\frac{3274 lbs CO\_{2} }{100, 000 L}=0.0116 lbs CO\_{2}/week$

1. **Total CO2 emissions**

0.0065$ lbs CO\_{2}/week$ (Refrigeration, 36%) + 0.0116$ lbs CO\_{2}/week$ (Truck Transport, 64%) = 0.018$ lbs CO\_{2}/week$ (total)



**Appendix Figure B1:** Pie chart generated by student LCA calculations of CO2 emissions from a can of soda (estimated cooling costs for one week and shipping viatruckfrom Atlanta to New York)

**References:**

1. Retrieved from <http://energyusecalculator.com/electricity_refrigerator.htm>
2. Retrieved from <https://www.eia.gov/tools/faqs/faq.php?id=74&t=11>