Georgia Tech — School of Civil & Environmental Engineering

School of Civil & Environmental Engineering, Georgia Institute of Technology

SUSTAINABLE ENGINEERING

CEE 8813C (82629) · 1:35 to 2:55 pm TR · Sustainable Education 110

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1. Instructor and TA

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2. Course Description

The course is intended to introduce students to the interaction between the human and natural environment, focusing on how the anthropogenic activities have altered the natural environment and provide an overview on the emerging science of *sustainability.* This course will identify the impacts associated with resource consumption and environmental pollution, and present the quantitative tools necessary for assessing environmental impacts and design for sustainability. At the end of the course, the students are expected to be cognizant about the concept of sustainability, the metrics of sustainability and be able to use the principles of sustainability in their respective field of practice.

3. Key Learning Points:

The key learning objectives would include:

- Indicators of Sustainability
- Earth Systems Engineering and Management
- Integration of the Environmental, Social and Economic Issues
- Life Cycle Analysis
    - Life Cycle Inventory
    - Risk and Impact Assessment
- Material Flow Analysis
    - Urban Metabolism
- Target Plots
- Industrial Ecology
- Urban Sustainability
- Dynamics of sustainability in the Developed and Developing world
- Agent-based Modeling
- Geoengineering
- Business Models of Sustainability

Engineering Working Definition of Sustainable Development:

Our socioeconomic system is far from sustainable and this may cause us guilt and perhaps frustration and so there may be a tendency to just give up. Consequently, we will use this definition for this class.

> Roy F. Weston: "Sustainable Development is a ***process of change*** in which the direction of investment, the orientation of technology, the allocation of resources, and the development and functioning of institutions that meet present needs and aspirations without endangering the capacity of natural systems to absorb the effects of human activities, and without compromising the ability of future generations to meet their own needs and aspirations."

A simpler working definition of sustainable engineering can be as follows:

> *Sustainable Engineering is the design of human and industrial systems to ensure that humankind's use of natural resources and cycles do not lead to diminished quality of life due either to losses in future economic opportunities or to adverse impacts on social conditions, human health and the environment.*

These requirements reflect that social conditions, economic opportunity, and environmental quality are essential if we are to reconcile society's development goals with international environmental limitations.

4. Class Operation

This course involves active learning on the part of the students. The class will be broken up into groups. Each group will work together on homework and final project.

Prerequisites:

This course is meant to be taken **by both engineering and non-engineering students**. It requires basic mathematical skills, and the willingness to conduct quantitative analyses. Especially for the group project, students with different backgrounds may be called upon to contribute in different ways.

Attendance:

Students should sign in at the beginning of each class. A sign-in sheet will be provided by the instructor.

Grading:

Homework and Class Participation	25%
Mid-Term Exam	25%
Journal Article Critique	10%
Class Project	40%

Homework:

Homework is to be done individually but you certainly can seek advice from your group and others.

Homework Assignments Format:

1. Unless the problems are very short, begin each problem on a new sheet.

2. Always restate the problem indicating the given information, desired information and explain your method. Make liberal use of comments.
3. Make liberal use of sketches.
4. Always use units in your calculations and on graphs. For quantitative problems please underline the final answers.
5. Above all, BE EXTREMELY NEAT.

Class Project:

Class Projects are to be worked on as a group. They represent a group effort and each group will write a group report. Sustainable solutions will require coordinated collective efforts with stakeholders with diverse opinions and objectives. The group projects should be considered an opportunity to explore this approach.

The report should not be unnecessarily long, but should contain the following elements:

Abstract. Most technical journals require abstracts which summarize the content of a paper in one or two paragraphs. The abstracts may be written in the form used in the scientific Journals. Please include concluding remarks in the abstract. Every statement in the conclusion should be capable of undergoing careful scrutiny.

Introduction. The introduction should provide the reader with a concise statement of the theoretical and rational basis. It would be appropriate to follow the form frequently used in the scientific Journals for the introduction and succeeding sections.

Approach. The approach that was used to gather, analyze and synthesize a solution to the issue should be discussed in this section. If this section is written correctly, the results and discussion section will be more concise and will focus only on the presentation of the results and interpret the results.

Results and Discussion. Results should be summarized, tabulated, or plotted neatly. Particular attention should be paid to the units employed. S.I. units are preferred. Sample calculations should be shown. This section of the report gives greatest insight into the integrity of the writers. It is very easy to over interpret results. Caution should be observed in interpreting the results and alternatives should be considered.

Future Research and/or Investigation. Most good investigations raise additional questions that can not be addressed without additional time, talent and resources. The section should help focus the reader on what should be undertaken next.

References Cited. Please refer to the American Chemical Society guideline for the format that should be used and the manner in which references are cited (http://pubs.acs.org/userimages/ContentEditor/1246030496632/chapter14.pdf).

10 to 15 pages of text, excluding references, tables and figures, is a good target for the paper. I expect you to use the basic principles that we discuss in class: 12 green engineering principles in your recommendations, LCA, material flow analysis. Also, I expect you to examine sustainability metrics.

5. Course Content

Week	Date	Content	Recommended Readings (readings would be posted on T-Square)
1	20-Aug	Class Introduction / Sustainability and Sustainable Engineering	• McIsaac, G.F., Morey, N.C. Engineers' role in sustainable development: Considering cultural dynamics, *Journal of Professional Issues in Engineering Education and Practice* **1998**, *124* (4), 110-119 • Crittenden. J.C. Engineering the quality of life. *Clean Techn. Environ. Policy* **2002**, 4, 6-7. • Mihelcic, J.R., et al. Sustainability science and engineering: The emergence of a new metadiscipline. *Environ. Sci. Technol.* **2003**, *37* (23), 5314-5324. • Sustainability and Engineering in New Zealand: Practical Guidelines for Engineers. • Xu, M; Crittenden, C; et al. Gigaton Problems Need Gigaton Solutions, *Environ. Sci. Technol.* **2010**, *44* (11), 4037-4041.
	22-Aug	Energy and Climate Change	• Chow, J., Kopp, R.J., Portney, P.R. Energy resources and global development. *Science* **2003**, *302*, 1528-1531. • Pacala, S., Socolow, R. Stabilization wedges: Solving the climate problem for the next 50 years with current technologies. *Science* **2004**, *305*, 968-972. • Washington, W.M., et al. How much climate change can be avoided by mitigation? *Geophys. Res. Lett.* **2009**, *36*, L08703. • Fargione, et al., Land Clearing and the Biofuel Carbon Debt, *Science* **2008,** *319*, 1235-1238. • Myhrvold, N.P., Caldeira, K., **2012**. Greenhouse gases, climate change and the transition from coal to low-carbon electricity. Environ. Res. Let, 7, 014019
2	27-Aug	Energy and Climate Change: Continued	
	29-Aug	Geoengineering: Carbon Cycle	• Wigley, T. M. L., A Combined Mitigation/Geoengineering Approach to Climate Stabilization. *Science* **2006,** 314, 452-454 • Victor, D. G., et al., The Geoengineering Option. *Foreign Affairs*, **2009**, *88*(2), 64-76 • Stavins, R. N; The Costs of Carbon Sequestration: A Revealed-Preference Approach. *The American Economic Review,* **1999**, *89* (4), 994-1009 • Kauppi, P; Sedjo, R; Technological and Economic Potential of Options to Enhance, Maintain, and Manage Biological Carbon Reservoirs and Geo-engineering, Chapter 4, *Climate Change 2001: Mitigation, IPCC Third Assessment Report*, **2001**, 301-344 • Rockström, J., et al., **2009**. A safe operating space for humanity. Nature 461, 472-475 • Barnosky, A.D., et al., **2012**. Approaching a state shift in Earth's biosphere. Nature 486, 52-58
3	3-Sep	Geoengineering: Other Natural Cycles	

Week	Date	Content	Recommended Readings (readings would be posted on T-Square)
	5-Sep	Material Flow Analysis	• Matthews, E., et al. *The Weight of Nations: Material Outflows from Industrial Economies*; World Resource Institute: Washington DC, 2000. • Bringezu, S., et al. International comparison of resource use and its relation to economic growth: The development of total material requirement, direct material inputs and hidden flows and the structure of TMR. *Ecol. Econ.* **2004**, *51*, 97-124. Gerst, M. D; Graedel, T. E; In-Use Stocks of Metals: Status and Implications. *Environ. Sci. Technol.* **2008**, *42* (19), 7038-7045.
4	10-Sep	Life Cycle Assessment	• ISO. *Environmental Management: Life Cycle Assessment, Principles and Framework*; ANSI/ISO 14040, **1997**. • Hendrickson, C., Horvath, A. Economic input-output models for environmental life-cycle assessment. *Environ. Sci. Technol.* **1998**, *32* (7), 184A-191A. • Williams, E.D., Ayers, R.U., Heller, M. The 1.7 kilogram microchip: Energy and material use in the production of semiconductor devices. *Environ. Sci. Technol.* **2002**, *36* (24), 5504-5510. • Hauschild, M.Z. Assessing environmental impacts in a life-cycle perspective. *Environ. Sci. Technol.* **2005**, *39* (4), 81A-88A. • Scientific Applications International Corporation (SAIC). *Life Cycle Assessment: Principles and Practice*; US EPA: Cincinnati, Ohio, **2006**. • Carnegie Mellon University Green Design Institute. *Economic Input-Output Life Cycle Assessment (EIO-LCA) Model*; http://www.eiolca.net/. • National Renewable Energy Laboratory (NREL). *U.S. Life-Cycle Inventory Database*; http://www.nrel.gov/lci/. • Duchin, F. Industrial input-output analysis: Implications for industrial ecology. *PNAS* **1992**, *89*, 851-855. • Lave, L.B., et al. Using input-output analysis to estimate economy-wide discharges. *Environ. Sci. Technol.* **1995**, *29* (9), 420A-426A. • Hendrickson, C.T.; Lave, L.B.; Matthews, H.S. *Environmental Life Cycle Assessment for Goods and Services, Chapter 2: Hybrid LCA Analysis*; Resources for the Future Press: Washington DC, **2006**.
	12-Sep	Life Cycle Assessment: Continued	
5	17-Sep	LCA Example on Water Treatment Technologies	
	19-Sep	*Preliminary Group Project Presentation*	
6	24-Sep	Grand Challenges for Sustainability	• Steffen, W., et al. *Global Change and the Earth System: A Planet under Pressure, Executive Summary*; Springer: Heidelberg, 2004. • Costanza, R., et al. Sustainability or collapse: What can we learn from integrating the history of humans and the rest of nature? *Ambio* **2007**, *36* (7), 522-527. • Liu, J., et al. Complexity of coupled human and natural systems. *Science* **2007**, *317*, 1513-1516. • Kolpin, D. W., et al. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: A national reconnaissance. *Environ. Sci. Technol.* **2002**, *36* (6): 1201-1211.
	26-Sep	Grand Challenges continued: Technology Solutions	

Week	Date	Content	Recommended Readings (readings would be posted on T-Square)
			• Allenby, B. The industrial ecology of emerging technologies. *J. Ind. Ecol.* **2009**, *13* (2), 168-183.
7	1-Oct	Risk Assessment: Target Plots, Pollution Prevention Assessment Framework, QSAR Model, Relative Risk Indices	• US EPA. *Pollution Prevention (P2) Framework*; 2005 • Cash, G.G. Prediction of chemical toxicity to aquatic organisms: ECOSAR vs. Microtox® Assay. *Environ. Toxicol. Water Qual.* **1998**, 13 (3), 211-216.
	3-Oct	Risk Assessment: Comparison of Two Industry Sectors, Reaction Pathway Selection	
8	8-Oct	Tools for Sustainable Engineering: 12 Principles for Sustainable or Green Engineering	• Anastas, P.T., Zimmerman, J.B. Design through the 12 principles of green engineering. *Environ. Sci. Technol.* **2003**, *37* (5), 94A-101A. • McDonough, W., et al., Applying the principles of green engineering to cradle-to-cradle design. *Environ. Sci. Technol.* **2003**, *37* (23), 434A-441A. • The President's Council on Sustainable Development. *Towards a Sustainable America;* 1999.
	10-Oct	Mid-term Examination	
9	15-Oct	*No Class. Student Recess*	
	17-Oct	Urban Sustainability: Introduction	• Grimm, N.B., et al. Global change and the ecology of cities. *Science* **2008**, *319*, 756-760. • Batty, M. The size, scale, and shape of cities. *Science* **2008**, *319*, 769-771.
10	22-Oct	Urban Sustainability: Urban Development Simulations, Air Quality and Heat Island Simulations, Cyberinfrastructure for Urban Sustainability	• Li, K., et al. Development of a framework for quantifying the environmental impacts of urban development and construction practices. *Environ. Sci. Technol.* **2007**, *41* (14), 5130-5136.
	24-Oct	Agent Based Modeling	• Bonabeau, E., Agent-based modeling: Methods and techniques for simulating human systems. *PNAS*. **2002**. 9, 7280-7287 • Macy, M. W; Willer, R; From Factors to Actors: Computational Sociology and Agent-Based Modeling. *Annual Review of Sociology*. **2002**, *28,* 143-166
11	29-Oct	*Interim Group Project Presentation*	
	31-Nov	Global Perspectives	• UN, The Millennium Development Goals Report, New York, **2005** • Rees, W. E; The built environment and the ecosphere: a global perspective, *Building Research & Information*, **1999**, *27*(4/5), 206-220
12	5-Nov	Introduction to Industrial Ecology	• Jelinski, L.W., et al. Industrial ecology: Concepts and approaches. *PNAS* **1992**, *89*, 793-797. • Frosch, R.A. Industrial ecology: A philosophical introduction. *PNAS* **1992**, *89*, 800-803. • von Hauff, M., Wilderer, P.A. Industrial ecology: Engineered representation of sustainability. *Sustain. Sci.* **2008**, *3*, 103-115.
	7-Nov	Metrics of Industrial Ecology: Thermodynamic Metrics and Environmental Metrics (Global Warming Potential)	
13	13-Nov	Metrics of Industrial Ecology: Other Environmental Metrics	

Week	Date	Content	Recommended Readings (readings would be posted on T-Square)
	14-Nov	Sustainability Metrics: Ecological Footprint, Genuine Progress Indicator, Environmental Sustainability Index	• Rees, W., Ecological footprints and appropriated carrying capacity: What urban economics leaves out. *Environment and Urbanization.* **1992**, *4*(2), 121-130. • Anielski, M; Rowe, J., *The Genuine Progress Indicator – 1998 Update.* **1999**. Redefining Progress • Esty, Daniel C., Levy, M; Srebotnjak, T; de Sherbinin, A., *2005 Environmental Sustainability Index: Benchmarking National Environmental Stewardship*. **2005** New Haven: Yale Center for Environmental Law & Policy.
14	19-Nov	Economic and Societal Sustainability: Ecological Economics	• Costanza, R; Daly, H. E., Toward an ecological economics. *Ecological Modelling*. **1987**, 38 (1-2), 1-7. • Costanza, R; et al; The value of the world's ecosystem services and natural capital, *Nature* **1997**, 387, 253-260 • Costanza, R; et al., Managing Our Environmental Portfolio. *BioScience*. **2000**, 50(2), 149-155.
	21-Nov	Legal and Political Realm of Sustainability, Business Models for Sustainability, Role of Engineers	• Viljoen, J; Defining a business model for sustainability – does one size fit all? **2008.** *World Export Development Forum* • Nidumolu, R; Prahalad, C. K., Rangaswami, M. R; Why Sustainability Is Now the Key Driver of Innovation, *Harvard Business Review*, **2009.** • Papadakis, K; Socially sustainable development and participatory governance: legal and political aspects, **2006,** International Institute for Labour Studies Geneva • Magretta, J; Growth through global sustainability. **1997**, *Harvard Business Review*, 79-88 • Hart, S. L; Milstein, M. B; Global Sustainability and the Creative Destruction of Industries, *Sloan Management Review*, **1999** (Fall), 23-33
15	26-Nov	*No Class. Prepare for Project Report*	
	28-Nov	*No Class. Thanksgiving Holiday*	
16	3-Dec	*Final Group Project Presentation*	
	5-Dec	*Final Group Project Presentation*	

6. Useful Links

UN website:

http://www.un.org/esa/sustdev/index.html	(UN Division of Sustainable Development)
http://www.unep.org/	(UN Environment Programme)

Indicators:

http://www.epa.gov/indicate/	(US EPA)
http://www.iisd.org/measure/	(International Institute for Sustainable Development)
http://themes.eea.eu.int/all_indicators_box	(European Union)
http://themes.eea.eu.int/index_html#Sectors_and_activities	(European Union)
www.sustainable-development.gov.uk/indicators/index.htm	(United Kingdom)
http://www.epa.gov/iwi/	(Watersheds)
http://www.epa.gov/ost/biocriteria/index.html	(Biocriteria)
http://www.worldbank.org/data/wdi2001/	(World Development Indicators)
http://www.met-office.gov.uk/research/hadleycentre/	(Climate Prediction & Research)

Construction:

http://www.rethinkingconstruction.org/	(Constructing Excellence)
http://www.cbpp.org.uk/	(Best Practices)
http:www.m4i.org.uk	(Movement for Innovation)
http://www.ciria.org.uk/	(Indicators)

Waste:

http://www.epa.gov/osw/	(US EPA)
http://ewasteguide.info/	(Electronic Wastes)

Energy:

http://www.esource.com/public/default.asp	(Energy Business Intelligence)
http://www.eren.doe.gov/	(Renewable Energy)
http://www.cee1.org/home.html	(Consortium of Energy Efficiency)

LCA:

http://iac.rutgers.edu/database/	(14,000+ Assessment)
http://hpb-1a.nrel.gov/lci/	(US LCI database)
http://www.epa.gov/nrmrl/lcaccess/	(US EPA)
http://www.life-cycle.org/	(LCA Links)
http://www.eiolca.net/	(CMU EIOLCA)

Listing of World Wide Environmental Agencies / NGO's:

http://www.worldbank.org/nipr/epas/index.htm	(Listing of Agencies)
http://gemi.org/	(Global Environnemental Management Initiative)
http://www.sustainablebusiness.com/	(Sustainable Business)
http://www.wbcsd.org/	(World Business Council on Sustainable Development)
http://www.ceres.org/	(Coalition for Environmentally Responsible Economies)
http://www.globalreporting.org/	(Global Reporting Initiative)
http://www.ulsf.org/	(University Leaders for a Sustainable Future)
http://www.sdcn.org/	(Sustainable Development Communications Network)
http://www.environmentalsustainability.info/	(Environment Portal & Search Engine)
http://www.secondnature.org/	(Second Nature – Sustainable Education)
http://www.sustainableliving.org/	(Sustainable Living Network)
http://www.ucsusa.org/	(Union of Concerned Scientists)

http://www.epa.gov/oppt/greenengineering/	(The Green Engineering Program)
http://www.epa.gov/dfe/	(Designing for Environment Program)
http://www.epa.gov/cpg/	(Comprehensive Procurement Guidelines Program)
http://www.epa.gov/sectors/	(The Industry Partners Program)
http://www.epa.gov/epaoswer/hazwaste/minimize/	
http://www.epa.gov/p2/	
http://www.epa.gov/oppt/p2framework/	(The P2 Program)
http://www.epa.gov/epaoswer/non-hw/reduce/epr/	(The Product Stewardship Program)

Sustainability-related Journals:

http://www3.interscience.wiley.com/journal/118902538/home	(Journal of Industrial Ecology)
http://pubs.acs.org/journal/esthag	(Environmental Science & Technology)
http://www.elsevier.com/locate/jclepro	(Journal of Cleaner Production)
http://www.elsevier.com/locate/ecolecon	(Ecological Economics)
http://www.elsevier.com/locate/energy	(Energy)
http://www.elsevier.com/locate/enpol	(Energy Policy)
http://www.elsevier.com/locate/jenvman	(Journal of Environmental Management)
http://www.springerlink.com/content/100370	(Environmental Management)
http://www.springerlink.com/content/120154	(Sustainability Science)
http://www.elsevier.com/locate/resconrec	(Resources, Conservation and Recycling)
http://www.scientificjournals.com/sj/lca/	(International Journal of Life Cycle Assessment)