

Sustainable Manufacturing, E290C

TuTh8:00AM-9:30AM, 3105 Etcheverry Hall

Instructor: D. Dornfeld (dornfeld@berkeley.edu)
<http://www.me.berkeley.edu/e290c/> and “b-space”

Course Description: Sustainable manufacturing is a poorly understood idea and one that is not intuitively connected to business value or engineering practice. This course will provide the basis for understanding (1) what is envisioned as sustainable manufacturing and how that relates to larger issues of global warming, energy independence, and social impact, (2) what comprises sustainable manufacturing practices in for-profit enterprises, (3) how to practice and measure continuous improvement using sustainability thinking, (4) techniques and tools for product and manufacturing process design and development, and (5) effective communication of sustainability performance to internal and external audiences. The primary focus of this course is manufacturing processes, systems and tooling/machinery including energy, materials, consumable and supply chain and distribution elements as they impact manufacturing.

Material in the course will be supplemented by speakers with diverse backgrounds in corporate sustainability, environmental consulting, and academia. Discussions of papers/references in a reader including case studies will be used to illustrate topics. A final class project will be required, with students working individually or in small groups in partnership with industrial contacts. Cross functional groups comprised of students from different academic backgrounds will be encouraged. Class projects will apply the analysis techniques covered in this course to design and develop environmentally mindful products or processes or analyze policies that lead to environmental improvements. Interaction with industry and collection of real-world data will be encouraged.

Requirements: Graduate standing or consent of instructor; useful background: ME 290E: Green Product Development, Design for Sustainability; ME220 Precision Manufacturing; ME221 Rapid Prototyping; and ME101 High Mix/Low Volume Manufacturing.

(Part of course offerings for Management of Technology (MOT) and Engineering and Business for Sustainability (EBS) program in the College of Engineering.)

Instructor: David Dornfeld is in the Mechanical Engineering Department and is the Will C. Hall Family Professor of Engineering; He is Director of the Laboratory for Manufacturing and Sustainability at Berkeley, imas.berkeley.edu.

E290C Syllabus/Course Outline Fall 2009

Week	Date	Topic/Reading*
1	(8/27)	Course introduction; overview, background and drivers for sustainable business and manufacturing; corporate sustainability; life cycle issues. (Can we define “sustainable” manufacturing?) <i>Reading:</i> Greening Chap 1 & 2; Natural Preface & Chap 1; Strategy Intro (1-16), Eco Chap 1, 10, 11; Hotair Chap 1.*
2	(9/1, 9/3)	Developing metrics for sustainable business practices, design and manufacturing; regulatory (US and global) considerations. <i>Reading:</i> Greening Chap 3; Natural Chap 2; Eco Chap 2, 5.
3	(9/8, 9/10)	Review of manufacturing tools, processes and systems (including the distribution and supply chain). <i>Reading:</i> Greening Chap 4; Natural Chap 3, 4, 6 & 7 Project team composition/project introduction.
4	(9/15, 9/17)	Analytical tools for sustainability assessment; life cycle assessment/impact (LCA/I) tools. (What is “green” manufacturing?) <i>Reading:</i> Greening Chap 5, 6 & 7; Natural Chap 8 & 9; Eco Chap 3-4. (Groups formed)
5	(9/22, 9/24)	Case study in manufacturing analysis for sustainability: i. Nanoscale manufacturing and energy of labor (tentative) and ii. Process technologies for alternative energy. <i>Reading:</i> Greening Chap 8 & 9, 26; (Project proposals due)
6	(9/29, 10/1)	Case study in manufacturing analysis for sustainability: iii. Solar panel manufacturing (tentative), iv. Semiconductor manufacturing (tentative). <i>Reading:</i> Greening Chap 11, 12 & 19; (Tu: Group Project Presentation)
7	(10/6, 10/8)	Case study in manufacturing analysis for sustainability: v. “Conventional” manufacturing, vi. Automotive or machine tool manufacturing (tentative). <i>Reading:</i> Greening Chap 17, 18 & 21
8	(10/13, 10/15)	Outside speaker 1: NGO/Deriving Business Value out of Sustainability Initiatives (tentative); Strategies for Sustainable Design; Natural Chap 13; Eco Chap 6, 7.
9	(10/20, 10/22)	Design, operation and control of sustainable manufacturing tools, processes and systems. <i>Reading:</i> Otto, <i>Product Design</i> , Chap 15 (b-space) and Poole, <i>Green Design</i> (b-space); Eco Chap 8; Outside speaker 2: Sustainability Thinking and Implementation in Business (tentative);
10	(10/27, 10/29)	Design, operation and control of sustainable manufacturing tools, processes and systems, cont’d. (Materials selection, etc.) Eco Chap 9.

11	(11/3, 11/5)	Green factories; Outside speaker 3: Green Design and Manufacturing in Consumer Products (tentative); <i>Reading</i> : Greening Chap 23, 24 & 25
12	(11/10, 11/12)	Outside speaker 4: Business strategy for sustainability; Product Stewardship in Industry (tentative); Sustainability communication and public reporting. <i>Reading</i> : Natural Chap 14 & 15
13	(11/17, 11/19)	Business models for sustainable manufacturing. <i>Reading</i> : Natural Chap 8; Greening Chap 27 and 28
14	(11/24)	Student project/paper presentations
15	(12/1, 12/3)	Student project/paper presentations; Course wrap-up;
16	(12/8)	Course wrap-up; report preparation.

***Reading Key:** **Greening** = Graedel and Howard-Grenville, *Greening the Industrial Facility*, 2005; **Natural** = Hawken *et al*, *Natural Capitalism: Creating the Next Industrial Revolution*, 1999; **Eco** = Ashby, *Materials and the Environment*; **Hotair** = Mackay, *Sustainable Energy – without the hot air*; and **Strategy** = Werbach, *Strategy for Sustainability*. (See course textbooks below)

Instructor

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Text

Required textbooks:

- M. F. Ashby, *Materials and the Environment: Eco-informed Material Choices*, Elsevier, 2009, ISBN: 978-1-85617-608-8 (\$62.95 at Amazon)

Recommended textbooks:

- T. E. Graedel and J. A. Howard-Grenville, *Greening the Industrial Facility*, Springer, 2005 (Amazon)
- David J. C. MacKay, *Sustainable Energy – without the hot air*, UIT, Cambridge England, 2009 (download at no charge at <http://www.withouthotair.com/download.html>)
- Paul Hawken, Amory Lovins and L. Hunter Lovins, *Natural Capitalism: Creating the Next Industrial Revolution*, Little, Brown and Company, Boston, 1999 (download at no charge at <http://www.natcap.org/sitepages/pid20.php>)
- Adam Werbach, *Strategy for Sustainability: A Business Manifesto*, Harvard Business Press, Boston, 2009 (\$16.50 at Amazon)

Web Site: <http://www.me.berkeley.edu/e290c/> and b-space;

NOTE: B-space is the primary source of information for this class!

Course Project

One major course project (group) will be required related to the course content and focus. Possible projects could be on one of the following general topic areas (NOT an exhaustive list!):

- metrics for assessing sustainable processes or systems
- sensors for energy/material/consumable/resource monitoring
- sustainable machine operation budget determination
- strategies for optimizing the energy/sustainable performance of production systems
- environmentally/sustainable machines/machine tool design
- process planning
- process modeling
- software for design and analysis of sustainable systems and processes
- “Cleantech” applied to production systems (from resource extraction to recycling)
- Web-based assessment/design tools
- Software material selection tools as applied to green analyses (e.g. Granta Design/Ashby)
- CAD based assessment/design tools (e.g. add-on to Solidworks)
- re-manufacturing
- business strategies for environmentally benign/sustainable manufacturing
- design “rules of thumb”
- material selection strategies
- LCA tools linked to process/system details
- Case studies of successful (or unsuccessful) attempts at green/sustainable processes/systems
- Tools/strategies for evaluation of social and natural resource impact
- Web-based resource tools for information on sustainable manufacturing
- Instrumentation for measuring/monitoring/assessing process/system/device performance

Other project topics may be chosen in consultation with the Instructor and may be ones associated with another graduate class you are enrolled in or your graduate studies. For example, students enrolled in another course may be interested in combining projects. A final project presentation and report is required. Special preference is given to projects which utilize or link to commercial CAD packages (AutoCAD or Solidworks, for example) for definition of machine/process behavior, spread sheet-driven simulations (or other software such as Labview) of errors, costs, process models, etc. or other computer/network-based software simulations including Java-based applets. Novel format (Video, You-tube format) presentations are also encouraged. You and your team may also develop “instructional” simulations or experiments for future E290C classes.

Industry projects: I am working on several “industry projects” meaning they are motivated by specific problems in an industry. So far, potential projects relate to:

- Automotive plant global alternative energy analysis
- Green machine tools
- Minimum automation manufacturing

More details and projects to come!

Groups may be formed at any time but must be in place by end of Week 4 (9/18) and proposal for group project submitted and approved by end of Week 5 (9/25). A presentation on group project ideas will be held in class on Tu 9/29 (Week 6).

Homework, Exams and Grading

- Homework will be assigned and due the following week unless otherwise indicated.
- There is no mid-term exam. The final exam is a take home exam/paper.
- The grade will be determined on the following basis:
 - Homework 25%
 - Project 45%
 - Final 30%
 - (exceptional class participation + 5-10%)

Academic Honesty

All students should be familiar with the Code of Student Conduct and know that the general rules and student rights stated in that document apply to this class (see <http://uga.berkeley.edu/SAS/osc.htm> and <http://students.berkeley.edu/osl/sja.asp>). Cheating on homework, projects or the final exam may result in a failing grade for the entire course. In all cases of alleged cheating, your actions will also be reported to the Office of Student Conduct for administrative review.

Additional Reading List and Sources of Information (not exhaustive!)

Reference Literature (some are on reserve in Eng'g Library- indicated with*)

*[Allenby, 1994] Braden R. Allenby and Deanna J. Richards, eds., *The Greening of Industrial Ecosystems*, National Academy Press, Washington, DC, 1994. ISBN 0-309-04937-7

*[AME, 2008] –, *Green Manufacturing: Case Studies in Leadership and Improvement*, Association for Manufacturing Excellence (AME), 2008. ISBN 978-1-56327-389-6

*[Birkland, 2002] Birkland, Janis, *Design for Sustainability*, Earthscan, London, 2002. ISBN 978-1-85383-897-2

*[Esty, 2006] Daniel C. Esty and Andrew S. Winston, *Green to Gold*, Yale University Press, New Haven, 2006. ISBN 0-300-11997-6

*[Graedel, 2005] Thomas E. Graedel and Jennifer A. Howard-Grenville, *Greening the Industrial Facility: Perspectives, Approaches and Tools*, Springer, 2005. ISBN 0-387-24306-2

[Hawken, 1993] Paul Hawken, *The Ecology of Commerce: A Declaration of Sustainability*, Collins, 1993. ISBN 0-88730-655-1

*[Hawken, 1999] Paul Hawken, Amory Lovins and L. Hunter Lovins, *Natural Capitalism: Creating the Next Industrial Revolution*, Little, Brown and Company, Boston, 1999. ISBN 0-316-35316-7

*[Hendrickson, 2006] Chris T. Hendrickson, Lester B. Lave and H. Scott Matthews, *Environmental Life Cycle Analysis of Goods and Services: An Input-Output Approach*, Resources for the Future, Washington DC, 2006. ISBN 1-933115-24-6

*[McDonough, 2002] William McDonough and Michael Braungart, *Cradle to Cradle*, North Point Press, 2002. ISBN 0-86547-587-3

[Otto, 2001] Kevin Otto and Kristin Wood, *Product Design*, Prentice-Hall, Upper Saddle River, NJ., 2001. ISBN 0-13-021271-7 (Chapter 15 Design for the Environment pp. 719-779) and http://cwx.prenhall.com/cgi-bin/binder/syl.cgi?site=otto_wood.

*[Poole, 2007] Buzz Poole, ed., *Green Design*, Mark Batty, New York, NY, 2007. ISBN 0-9762245-8-5

*[Seliger, 2004] Gunther Seliger, Nabil Nasr, Bert Bras and Leo Alting, eds., *Proceeding Global Conference on Sustainable Product Development and Life Cycle Engineering*, Uni-Edition, Berlin, 2004. ISBN 3-937151-21-4

*[Tester, 2005] Jefferson Tester, Elisabeth Drake, Michael Driscoll, Michael Golay and William Peters, *Sustainable Energy: Choosing Among Options*, MIT Press, Cambridge, MA, 2005. ISBN 0-262-20153-4

Other Links of interest:

- Wuppertal Institute: http://www.wupperinst.org/FactorFour/FactorFour_links.html
- Japan for Sustainability: <http://www.japanfs.org/>; specially publications such as industry sustainability reports: http://www.japanfs.org/en/business/reports_cat_13.html
- Rocky Mountain Institute <http://www.rmi.org/sitepages/pid23.php>
- Greenblue: <http://www.greenblue.org/>
- Energy Information Agency (US Gov't) <http://www.eia.doe.gov/>

(Others posted on b-space)

Other Sources of Information

Topic
<p>Environmental issues with industry</p> <ol style="list-style-type: none"> Allen D. T, Shonnard D. R., Green Engineering, Environmentally Conscious Design of Chemical Processes. An Introduction to Environmental Issues, Chapter 1, pp. 3-30 UNEP, Global environmental outlook, 2000, Overview, http://www.unep.org/geo2000/ov-e/index.htm, 2006 annual report http://www.unep.org/publications/search/pub_details_s.asp?ID=3919
<p>Risk, Health impacts, Environmental Justice</p> <ol style="list-style-type: none"> Slovic P., "Trust, emotion, sex, politics, and science: surveying the risk assessment battlefield," Risk Analysis 19 (4), p.. 689-700, http://www.kluweronline.com/article.asp?PIPS=220830 Auberson-Huang L., "The dialogue between precaution and risk," Nature, Vol. 20 (11), 2002, pp. 1076-1078, http://www.nature.com/cgi-taf/DynaPage.taf?file=/nbt/journal/v20/n11/full/nbt1102-1076.html World Health Organization, The world health report 2002, Overview and Chapter 4, Page 10, http://www.who.int/whr/2002/en/; and The world health report 2007 - A safer future: global public health security in the 21st century, http://www.who.int/whr/2007/en/index.html
<p>Regulations</p> <ol style="list-style-type: none"> "Environmental Law: Exploring the Influence on Engineering Design," http://css.snre.umich.edu/makeframe.php?content=css_edu_resources
<p>Design for Environment (DFE) and Green Manufacturing</p> <ol style="list-style-type: none"> Green Products by Design: Choices for a Cleaner Environment, September 1992, OTA-E-541, policy.rutgers.edu/andrews/courses/9221.pdf, Summary (Chapter 1) and Chapter 2: Materials and design. Fitzgerald, D. et al, Beyond Tools: A Design for Environment Process, Int. J. of Performance Engineering, 1, 2, Oct 2005, pp. 105-120. http://scholar.google.com/scholar?q=1.%09+%E2%80%9CEnvironmental+Law:+Explorin+g+the+Influence+on+Engineering+Design.%E2%80%9D+&hl=en&client=firefox-a&rls=org.mozilla:en-US:official&hs=kLJ&um=1&ie=UTF-8&oi=scholart
<p>Design for Environment</p> <ol style="list-style-type: none"> Green Products by Design: Choices for a Cleaner Environment, September 1992, OTA-E-541, policy.rutgers.edu/andrews/courses/9221.pdf, Chapter 3 (DFX) Fiskel J., Chapter 8: Practical DFE guidelines, From: Design for environment: Creating eco-efficient products and processes, McGraw Hill, 1996, pp. 91-111. Allenby B., The conceptual framework of DFE at AT&T, From: Design for environment: Creating eco-efficient products and processes, Fiskel J., ed., McGraw Hill, 1996, pp. 155-177
<p>Life Cycle Assessment (LCA)</p> <ol style="list-style-type: none"> Green Products by Design: Choices for a Cleaner Environment, September 1992, OTA-E-541, policy.rutgers.edu/andrews/courses/9221.pdf, Chapter 4, Strategies for Green Design McDonald's case study, the clamshell controversy http://www.umich.edu/~nppcpub/resources/compendia/ind.ecol.html
<p>Alternative LCA techniques</p> <ol style="list-style-type: none"> Hendrickson C., Horvath A., Joshi S., Lave L., "ECONOMIC INPUT-OUTPUT MODELS FOR ENVIRONMENTAL LIFE-CYCLE ASSESSMENT," Environmental Science & Technology. 32(7):A 184-A 191, 1998 Apr 1. Designing the perfect green product: SLCA in reverse Graedel, T.E.; Electronics and the Environment, 1997. ISEE-1997., Proceedings of the 1997 IEEE International Symposium on , 5-7 May 1997 Page(s): 317 -321.
<p>Green Manufacturing Primer</p> <ol style="list-style-type: none"> Assessment of Environmentally Benign Manufacturing (EBM) Technologies, http://www.wtec.org/loyola/ebm/, Executive summary, Chapter 1.

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1. Assessment of Environmentally Benign Manufacturing (EBM) Technologies, <http://www.wtec.org/loyola/ebm/>, Chapter 5: Materials and Products (Metals, polymers)
2. Dornfeld, D. and Wright, P., "Technology Wedges for Implementing Green Manufacturing," Trans. North American Manufacturing Research Institute, 2007, vol. 35, pp. 193-200.