Course Syllabi

- *Methods in Science and Technology Policy*
  Clinton Andrews, Princeton University
- *Domestic Policy Analysis: Environmental Planning*
  Clinton Andrews, Princeton University
- *Strategies for Environmental Management*
  Garry Brewer and Stuart L. Hart,
  University of Michigan
- *Environmental Science and Public Policy: Reducing Industrial Waste*
  William Clark, Michael McElroy, and Robert Frosch,
  Harvard University
- *Proposal for a Curriculum in Ecological and Development Economics*
  Faye Duchin, New York University
- *Industrial Ecology and Green Design*
  Robert Frosch, William Clark, and Michael McElroy,
  Harvard University
- *Industrial Ecology: Theory and Practice*
  Gregory A. Keoleian, University of Michigan
- *Introduction to Energy and Environmental Problems*
  R. H. Socolow, Princeton University

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Pollution Prevention and Industrial Ecology
NATIONAL POLLUTION PREVENTION CENTER FOR HIGHER EDUCATION

Methods in Science and Technology Policy

Clinton Andrews
WWS 589, Spring 1993
Woodrow Wilson School , Princeton University

Princeton University
Woodrow Wilson School
Graduate Program

Spring Term - 1993

WWS 589: Methods in Science and Technology Policy

Professor Clinton Andrews
Fridays, 9:00 am - 12:10 pm

This course introduces a set of tools that are widely used by practitioners of science and technology policy analysis. The focus is on the development of an operational understanding of applied techniques for modeling, risk assessment, and technology assessment. This course complements WWS 588 (Science, Technology and Public Policy), and is a requirement for the Certificate in Science, Technology and Public Policy. Major topics include the following:

Modeling: This module introduces a set of widely applicable modeling tools, starting on the back of an envelope with order-of-magnitude estimation, and proceeding to computer-assisted analysis of stocks and flows in dynamic systems. We learn to develop growth projections with an emphasis on disaggregate "bottom-up" approaches that contrast with the more aggregate "top-down" methods popular in economics. We acquaint ourselves with STELLA II, a popular computer package for analyzing dynamic systems. Since humans now have the potential to drastically alter the world, by design or by accident, we examine two limiting applications: conditions of exponential population and/or economic growth under apparent resource constraints, and growth in technological capability relative to the scales at which natural systems operate.

Risk Assessment: Many science and technology policy decisions involve uncertainty and significant hazards. This module introduces a set of popular risk assessment tools developed for public health, environmental, military, and industrial applications. We critically explore the modeling methods of probabilistic risk assessment and exposure assessment, and the special problems of non-threshold risks such as carcinogens. We focus on policy-relevant aspects of those tools, specifically risk perceptions and risk-benefit analysis applications. Finally, we examine issues of political legitimation, including risk communication and prioritization.

Technology Assessment: The wide-ranging field of technology assessment addresses project evaluation questions, product evaluations, and questions of technology diffusion, transfer, and regulation. Project evaluation, or choosing among investment alternatives, is a key decision making activity. We critically review the methods of cost-benefit analysis and

multi-criteria analysis, with a special focus on demand-side options. Product evaluation emphasizes the societal implications of consumer product design choices. Using life-cycle analysis and materials balance accounting methods, we examine a set of classic product design questions (Styrofoam vs. paper cups).

Innovation does not instantly transform the industrial landscape. It must penetrate the marketplace. Thus we introduce a set of market assessment methods, and models of technology life-cycles, diffusion, and transfer. Informing real decisions – often nearly in real time – is also one of the key tasks of practicing policy analysts. We examine methods for structuring decisions to allow quantitative analysis of policy options, relevant uncertainties, and decision makers' preferences, for both the individual and multi-party decision contexts. Finally, we end the semester with a look at research management tools – productivity indicators and methods of portfolio evaluation – used at the point where science meets technology under the influence of policy.

Course Prerequisites: Students should be comfortable with statistical concepts at least at the level of WWS 507b, and preferably WWS 507c, although equivalent preparation is acceptable with permission of the instructor. A background in microeconomics at the level of WWS 511b is recommended. Students should also have basic familiarity with microcomputer tools such as spreadsheets, and should be comfortable with the Macintosh platform. Tutorials on the use of the Apple Macintosh, the Microsoft Excel spreadsheet, and the Lotus 123 spreadsheet are available in the computer room.

Course Requirements: There will be one three-hour class session each week. Half of each session will be a formal lecture devoted to concepts, and the other half will be a highly participatory practicum. Depending on the week, the practicums will consist of in-class exercises, topical discussions, or a review of questions on the homework. Grades will be based on ten brief homework assignments, essentially one per week (75%), and a short research paper (25%). The homework assignments, some involving microcomputer work, will consist of short exercises (1 or 2 pages) applying the methods learned to simplified cases. Homework assignments will be due on the Monday afternoon following each Friday's class, so that they may be graded in time for the next class. In the final paper (length ≤ 15 pages) you should apply one or more of the techniques learned to a science and technology policy problem of your own choosing.

Schedule of Classes

Date	Topic
2/5	Introduction and overview, order-of-magnitude estimation
2/12	Modeling I: Growth projections, bottom-up vs. top-down approaches
2/19	Modeling II: Stocks and flows, natural scales and human impacts
2/26	Modeling III: Dynamics of systems, monitoring and feedback loops
3/5	Risk Assessment I: Modeling risks, actuarial, epidemiological, and probabilistic risk analysis approaches
3/12	Risk Assessment II: Policy analysis, risk-benefit analysis, psychometrics
3/26	Risk Assessment III: Political legitimation, communicating and prioritizing risks
4/2	Technology Assessment I: Project evaluation, benefit-cost analysis, multi-criteria analysis
4/9	Technology Assessment II: Product evaluation, life-cycle analysis, materials balance accounting
4/16	Technology Assessment III: Diffusion & transfer, regulation, market analysis, vintaging issues
4/23	Technology Assessment IV: Structuring decisions, decision analysis, uncertainty, multi-party context
4/30	Technology meets science (in R&D), summary and wrap-up

Books recommended for purchase (but also on reserve in the WWS library) include the following:

Harte, J., Consider a Spherical Cow: A Course in Environmental Problem Solving, Los Altos, CA: William Kaufmann Inc., 1985.

High Performance Systems, STELLA II, software for the Macintosh, student package, Hanover NH: High Performance Systems, 1992.

Krimsky, S., and D. Golding, eds., Social Theories of Risk, Westport CT: Praeger, 1992

Meadows, D. H., D. L. Meadows, and J. Randers, Beyond the Limits, Chelsea Green: Post Mills, VT, 1992.

Detailed Class Schedule, Readings, and Assignments

Date	Topic	
2/5	**Theory:**	**Introduction and overview**
	Practice:	**Order-of-magnitude estimation**
2/12	**Theory:**	**Modeling I: Growth projections**
	Practice:	**Bottom-up vs. top-down approaches**

Required Reading:

Krueckeberg, D. and A. Silvers (1974), Urban Planning Analysis: Methods and Models, John Wiley & Sons, New York, Chapter 8: Projecting Population, pp. 259-287.

Meadows, D. H., D. L. Meadows, and J. Randers, Beyond the Limits, Chelsea Green: Post Mills, VT, 1992, ch. 1 (overshoot) and 2 (the driving force: exponential growth), pp. 1-43.

U.S. Congress, Office of Technology Assessment, Changing by Degrees: Steps to Reduce Greenhouse Gases, OTA-O-482, Washington DC: U.S. Gov't Printing Office, 1991, chapters 1 (summary) and 4 (the buildings sector), pp. 1-42, 113-145.

Edmonds, J. and J. Reilly (1983), "A long-term global energy-economic model of carbon dioxide release from fossil fuel use," Energy Economics, April issue, pp. 74-88.

Jackson, J. (1988), "The Commercial Energy Demand Modeling System," Holyoke MA: NEPOOL, pp. 1-11, 23-60.

von Hippel, Frank, "Peer Review of Public Policy," in Citizen Scientist, New York: Simon & Schuster, 1991, pp. 16-29.

Edesess, M. and G. A. Hambrecht (1980), "Scenario forecasting: Necessity, not choice," The Journal of Portfolio Management, Spring issue, pp. 10-15.

In-Class Practicum:

Compare the policy-relevant strengths and weaknesses of energy forecasts that are "bottom-up" (OTA, J. Jackson) versus "top-down" (Meadows, Edmonds & Reilly).

Assignment (due 2/15/93):

Using the Statistical Abstract of the United States (on reserve in the WWS Library) as your data source, estimate the total population of the United States in the Year 2020, using (a) a "top down" linear, exponential, or asymptotic modeling approach; and (b) the "bottom-up" cohort-survival method. This is easiest to do using a spreadsheet (e.g., Lotus 123, Excel). A good tutorial also on reserve at the WWS Library is: Li, R. M., "Making an age pyramid on Lotus 1-2-3," mimeo, WWS, 1989. Comment briefly (a paragraph or two) on the differences among your results, and how they compare with government projections found in the pre-1992 Statistical Abstracts.

2/19 Theory: Modeling II: Stocks and flows
Practice: Natural scales and human impacts

Required Reading:

Harte, J., Consider a Spherical Cow: A Course in Environmental Problem Solving, Los Altos, CA: William Kaufmann Inc., 1985, pp. 21-64.

Meadows, D. H., D. L. Meadows, and J. Randers, Beyond the Limits, Chelsea Green: Post Mills, VT, 1992, ch. 3 (the limits: sources and sinks), pp. 44-103.

High Performance Systems, An Introduction to Systems Thinking, Hanover NH: High Performance Systems, 1992, ch. 1-6, pp. 1-102.

Recommended Reading:

High Performance Systems, STELLA II Tutorial and Technical Documentation, Hanover NH: High Performance Systems, 1992, skim Part 1.

In-Class Practicum:

Test the STELLA II systems dynamics modeling package.

Assignment (due 2/22/93):

Build a stock-and-flow model of a system of your choice using the STELLA II package. Prepare a brief (about one page) explanation of your model, and hand in the model and explanation on a floppy disk.

2/26 Theory: Modeling III: Dynamics of systems
Practice: Monitoring and feedback loops

Required Readings:

Joskow, P. L., and D. B. Marron, "What does a negawatt really cost? evidence from utility conservation programs," Energy Journal, vol. 13, no. 4, pp. 41-74.

Meadows, D. H., D. L. Meadows, and J. Randers, Beyond the Limits, Chelsea Green: Post Mills, VT, 1992, ch. 4-7, Appendix, pp. 104-217, 237-253.

High Performance Systems, Introduction to Systems Thinking, Hanover NH: High Performance Systems, 1992, ch. 7-9, pp. 103-170.

Recommended Reading:

As an engineering-oriented alternative to Joskow & Marron. Fels, M. F., and C. L. Reynolds, "Toward standardizing the measurement of whole-building energy savings in DSM programs," Energy Program Evaluation Conference, proceedings, Chicago, August 1991, pp. 75-85.

High Performance Systems, STELLA II Tutorial and Technical Documentation, Hanover NH: High Performance Systems, 1992.

In-Class Practicum:

Test the World3 model using STELLA II.

Assignment (due 3/1/93):

Read one of the critiques of the World3 model, e.g.: Simon, J., and H. Kahn, The Resourceful Earth, Oxford: Basil Blackwell, 1984; or Vargish, T., "Why the person sitting next to you hates *Limits to Growth*," Technological Forecasting and Social Change, vol. 16, 1980, pp. 179-189. Then perform your own critical evaluation of the World3 model using the STELLA II package. Next, revise the model, explaining what you

changed and why (in about one page). Hand in a disk with your revised model and evaluation.

3/5 **Theory:** **Risk Assessment I: Modeling Risks**
Practice: **Actuarial, Epidemiological, and Probabilistic Risk Analysis Approaches**

Required Reading:

Renn, O., "Concepts of risk: a classification," ch. 3 in Krimsky, S., and D. Golding, eds., Social Theories of Risk, Westport CT: Praeger, 1992, pp. 53-79.

Billinton, R., and R. N. Allan, Reliability Evaluation of Engineering Systems: Concepts and Techniques, New York: Plenum Press, 1983, ch. 4, 5, pp. 62-123.

Dougherty, E. M., and J. R. Fragola, Human Reliability Analysis, New York: John Wiley & Sons, 1988, Appendix, pp. 189-202.

Marsh, G. M., and R. Day, "A model standardized risk assessment protocol for use with hazardous waste sites," Environmental Health Perspectives, vol. 90, 1991, pp. 199-208.

U.S. Environmental Protection Agency (EPA), Risk Assessment Guidance for Superfund: Human Health Evaluation Manual, Part A, Washington DC: EPA, December 1989.

Recommended Reading:

U. S. Environmental Protection Agency, Environmental Risk: Your Guide to Analyzing and Reducing Risk, Washington: USGPO, 1991-545-607, 16 pp.

Billinton, R., and R. N. Allan, Reliability Evaluation of Engineering Systems: Concepts and Techniques, op. cit., ch. 1, 2, pp. 1-35.

In-Class Practicum:

Work through an example using the EPA RAGS method.

Assignment (due 3/12/93):

Each of four working groups will evaluate one of the four appendices to the EPA *Unfinished Business* report, and be prepared to share their

findings with the class as a whole during next week's class, taking no more than 20 minutes per group.

3/12 Theory: Risk Assessment II: Policy Analysis
Practice: Risk-benefit analysis, Psychometrics

Required Reading:

Hall, J. V., A. M. Winer, M. T. Kleinman, F. W. Lurman, V. Brajer, S. D. Colome, "Valuing the health benefits of clean air," Science, vol. 255, 14 February 1992, pp. 812-817.

Slovic, P., "Perception of risk: reflections on the psychometric paradigm," ch. 5 in Krimsky, S., and D. Golding, eds., Social Theories of Risk, Westport CT: Praeger, 1992, pp. 117-152.

von Winterfelt, D., "Expert knowledge and public values in risk management: the role of decision analysis," ch. 14 in Krimsky, S., and D. Golding, eds., Social Theories of Risk, Westport CT: Praeger, 1992, pp. 321-342.

U. S. Environmental Protection Agency, Office of Policy Analysis and Office of Policy, Planning, and Evaluation, Unfinished Business: A Comparative Assessment of Environmental Problems, Overview Report and Appendices I-IV, Washington DC: USEPA, 1987. Read overview and appendix appropriate for your working group.

U. S. Environmental Protection Agency, Science Advisory Committee, Reducing Risks: Setting Priorities and Strategies for Environmental Protection,Report SAB-EC-90-021 and 021A, Washington DC: USEPA, 1990, 26 pp.

Recommended Reading:

Kunreuther, H., "A conceptual framework for managing low-probability events," ch. 13 in Krimsky, S., and D. Golding, eds., Social Theories of Risk, Westport CT: Praeger, 1992, pp. 301-320.

National Research Council, Risk Assessment in the Federal Government: Managing the Process, Washington DC: National Academy Press, 1983, ch. 1, pp. 17-50.

In-Class Practicum:
Each of four working groups will present their evaluation of one of the four appendices to the EPA *Unfinished Business* report.

Assignment (due 3/22/93):
Prepare a one page term paper abstract.

Spring Break

3/26 Theory: Risk Assessment III: Political Legitimation
Practice: Communicating and Prioritizing Risks

Required Reading:

Nero, A., Jr., "Controlling Indoor Air Pollution," Scientific American, May 1988, pp. 42-48.

Kasparson, R. E., "The social amplification of risk: progress in developing an integrative framework," ch. 6 in Krimsky, S., and D. Golding, eds., Social Theories of Risk, Westport CT: Praeger, 1992, pp. 153-178.

Freudenburg, W. R., "Heuristics, biases, and the not-so-general publics: expertise and error in the assessment of risks," ch. 10 in Krimsky, S., and D. Golding, eds., Social Theories of Risk, Westport CT: Praeger, 1992, pp. 229-249.

Chess, C., M. Tamuz, A. Saville, and M. Greenberg, "Reducing uncertainty and increasing credibility: the case of Sybron Chemicals Inc.," Industrial Crisis Quarterly, vol. 6, 1992, pp. 55-70.

Greenberg, M., and D. Wartenberg, "Communicating to an alarmed community about cancer clusters: a fifty state survey," Journal of Community Health, vol. 16, no. 2, April 1991, pp. 71-82.

Greenberg, M., and D. Wartenberg, "Newspaper coverage of cancer clusters," Health Education Quarterly, vol. 18(3), Fall 1991, pp. 363-374.

Recommended Reading:

Wynne, B., "Risk and social learning: reification to engagement," ch. 12 in Krimsky, S., and D. Golding, eds., Social Theories of Risk, Westport CT: Praeger, 1992, pp. 275-297.

Greenberg, M., H. Spiro and R. McIntyre, "Ethical Oxymora for Risk Assessment Practitioners," Accountability in Research, vol. 1, Gordon & Breach Science Publishers S.A., pp. 245-257.

In-Class Practicum:

Classroom discussion of Radon problem.

Assignment (due 3/29/93):

Write a one page guidance for risk communication practitioners, specifying, in cookbook fashion, a process for informing the public policymaking process about a hazard of your choice.

4/2 Theory: Technology Assessment I: Project evaluation
Practice: Benefit-cost analysis, multi-criteria analysis

Required Reading:

Schofield, J., Cost-Benefit Analysis in Urban and Regional Planning, London: Allen and Unwin, 1987, pp. 1-77 (ch. 1- 6).

DeGormo, E., W. Sullivan and J. Bontadelli (1988), Engineering Economy, 8th edition, New York NY: MacMillan and Co., pp. 23-59 (chapter 2).

Electric Power Research Institute (EPRI), Cost-benefit analysis of demand-side planning alternatives, EPRI-EM-5068, prepared by Decision Focus Inc., Palo Alto CA: EPRI, 1987.

Andrews, C. J., "The marginality of regulating marginal investments: why we need a systemic perspective on environmental externality adders," Energy Policy, vol. 20, no. 5, May 1992, pp. 450-463.

Recommended Reading:

U.S. Department of Energy, Energy Information Administration, Annual Outlook for Electric Power 1985, DOE/EIA-0474(85), Washington DC: USGPO, pp. 1-26, 47-58 (ch. 1-3, Appendix A).

In-Class Practicum:

Comparison of alternative electric power system investments.

Assignment (due 4/5/93):

Limiting yourself to about one page, sketch out an electric utility integrated resource planning decision technique and provide a sample

calculation demonstrating how environmental factors are taken into account.

4/9 Theory: Technology Assessment II: Product evaluation
Practice: Life-cycle analysis, materials balance accounts

Required Reading:

Environmental Health & Safety Management, "Lifecycle assessments still too green to be used in product certifications," vol. 2, no. 4, November 25, 1991, pp. 1-2.

Allenby, B. R., "Design for environment: a tool whose time has come," Semiconductor Safety Association Journal, September 1991, pp. 5-9.

Gatenby, D.A., and G. Foo, "Design for X (DFX): key to competitive, profitable products," AT&T Technical Journal, May/June 1990, pp. 2-13.

Society of Environmental Toxicology and Chemistry (SETAC), "A technical framework for life-cycle assessments," 1990 workshop proceedings, SETAC Foundation, Pensacola FL, January 1991.

Hocking, M. B., "Paper vs. polystyrene: a complex choice," Science, 251:504-5 F 1 '91; and subsequent discussion: 252:1361-3 Je 7 '91.

U.S. Congress, Office of Technology Assessment, Green Products by Design: Choices for a Cleaner Environment, OTA-E-541, Washington DC:USGPO, 1992, pp. 3-20 (executive summary).

In-Class Practicum:

Test Volvo Corporation's environmental indexing tool.

Assignment (due 4/12/93):

Design a multi-criterion environmental rating scheme suitable for use with mass marketed consumer products, and provide an illustrative example. Limit yourself to about one page.

4/16 Theory: Technology Assessment III: Diffusion & transfer
Practice: Regulation, market analysis, vintaging issues

Required Reading:

Linstone, and Sahall (1976) Technology Substitution, Chapters 1, 13.

Lee, T. and N. Nakicenovic (1987), "Technology Life Cycles and Business Decisions," presented at Colloque International: Cycles de Vie et Cycles Longs, International Institute for Appied Systems Analysis, Laxenburg Austria.

Wells, L. (1972), "The Product Life Cycle Approach," in L. Wells, ed. The Product Life Cycle and International Trade, Division of Research, Harvard Business School, Cambridge MA, pp. 3-33.

Giese, R., P. Jones and B. Kroetch (1983), "Electric Vehicles: Market Penetration and Positive Externalities," Technological Forecasting and Social Change, Vol. 24, pp. 137-152.

Olson, J. and S. Choi (1985), "A Product Diffusion Model Incorporating Repeat Purchases," Technological Forecasting and Social Change, Vol. 27, pp. 385-397.

In-Class Practicum:

Discussion on the descriptive vs. predictive value of diffusion analysis.

Assignment (due 4/19/93):

Using STELLA II, build a diffusion model for a technology of your choice. Consider the customer's decisionmaking process, the factors affecting successful market entry, and the possible need for policy interventions. Briefly (about 1 page) explain your model and key results, and hand in the model and explanation on a floppy disk.

4/23 Theory: Technology Assessment IV: Structuring decisions
Practice: Decision analysis, uncertainty, multi-party context

Required Reading:

Janssen, R., Multiobjective decision support for environmental problems, Vrije Universiteit te Amsterdam, Netherlands, 1991, pp. 1-15 (Ch. 1).

Andrews, C. J., "Sorting out a consensus: analysis in support of multi-party decisions," Environment and Planning B: Planning and Design, vol. 19, 1992, pp. 189-204.

Keeney, R. and H. Raiffa, Decisions with multiple objectives: preferences, and value tradeoffs, John Wiley and Sons, New York, 1976, pp. 31-65, 436-472, 515-547 (Ch. 2, 8, 10).

Recommended Reading:

Andrews, C. J., and S. R. Connors, "Existing capacity – the key to reducing emissions," Energy Systems and Policy, vol. 15, pp. 211-235.

In-Class Practicum:

Design of an integrated resource planning process for the electric power sector.

Assignment (due 4/26/93):

Apply the STELLA II diffusion model you developed above under conditions of controversy and uncertainty. Demonstrate how you will address these issues. Briefly (about 1 page) explain your method and key results, and hand in the model and explanation on a floppy disk.

4/30 Theory: Technology meets science (in R&D)
Practice: Summary and wrap-up

Required Reading:

Kline, S.J., and D. E. Kash, "Do we need a technology policy?," IEEE Technology and Society Magazine, vol. 11, no. 2, pp. 18-25.

Markusen, A., and J. Yudken, "Building a new economic order," Technology Review, vol. 95, no. 3, April 1992, pp. 22-30.

Rothwell, R., "The impact of regulation on innovation: some U.S. data," Technological Forecasting and Social Change, vol. 17, 1980, pp. 7-34.

Sutherland, R., "An analysis of the USDOE civilian R&D budget," Energy Journal, vol. 10, no. 1, May 1989.

White, D. W., C. J. Andrews, and N. W. Stauffer, "The new team: electricity without global warming," Technology Review, vol. 95, no. 1, January 1992, pp. 42-50.

Elton, E. J., and M. J. Gruber, Modern Portfolio Theory and Investment Analysis, 3rd edition, New York: John Wiley & Sons, pp. 261-279, 571-608 (ch. 11, 22).

Recommended Reading:

Entingh, D. J., C. J. Andrews, D. C. Kenkeremath, J. E. Mock, F. T. Janis, Guidebook for Technology Transfer Managers: Moving Public R&D to the Marketplace, Meridian/ICFAR, Alexandria VA, 1987.

In-Class Practicum:

Revise the energy R&D portfolio for the United States.

5/16 Final Paper Due

Pollution Prevention and Industrial Ecology
NATIONAL POLLUTION PREVENTION CENTER FOR HIGHER EDUCATION

Domestic Policy Analysis: Environmental Planning

Clinton Andrews
WWS 527a, Fall 1992
Woodrow Wilson School, Princeton University

Princeton University
Woodrow Wilson School
Graduate Program

Fall Term - 1992

WWS527a
Domestic Policy Analysis:
Environment Planning

Professor Clinton Andrews
Office: 204 Robertson Hall
Telephone: 8-4835

Thursday 1:00 - 4:10 pm

The purpose of this course is to explore environmental issues from the planner's perspective, highlighting the institutional, perceptual, procedural and technical factors that influence environmental decisionmaking. It introduces a set of key environmental topics and then puts them into the planning context using case studies and in-class exercises. While the course works with scientific and technological data, the focus is on how planners manage such information rather than how experts generate it. It differs from environmental policy offerings in devoting a significant amount of time to the exploration of systematic approaches to decisionmaking and the development of technically defensible arguments.

Major topics are addressed at two levels: first with an overview lecture on conceptual issues (during the first hour-and-a-half of class), and then with a case or exercise emphasizing practical considerations (during the remaining hour-and-a-half). General issues include the following: planning philosophy, environmental externalities and the role of government, conceptions of nature and resources, public participation, scientific uncertainty and risk, systems thinking, regulatory design and industry response, and technological optimism.

Practical skills developed during this course include aspects of site evaluation, land use planning, demand forecasting, systems simulation, impact assessment, risk assessment, cost-benefit analysis, multi-criteria analysis and communicative planning. These skills will be applied in cases that provide exposure to the different levels of environmental planning: a local siting problem, a state land use controversy, a regional energy debate, and a global environmental issue.

Much of the context for today's environmental debates is affected by the first generation of environmental regulation, which was based on negative prescriptions, static perceptions of both technology and the environment, and adversarial interactions. This course acknowledges that history, but focuses more on the needs of an evolving second generation approach to environmental planning. These include the design of regulations to better harness market forces and encourage technological innovation, recognition of the dynamic behavior of natural and technological systems, and a need to plan in ways that produce stable, fair and efficient tradeoffs among multiple objectives.

Course requirements include participation in classroom cases/exercises and discussions, including development of brief in-class presentations and short written handouts (30%), a mid-term exam (20%), and preparation of a term paper on an environmental planning subject due at the end of reading period (50%).

Schedule of Topics, Reading, and Assignments

9/17 **Theory:** **Introduction and Course Overview**
Practice: **Introductory Case Study**

9/24 **Theory:** **Planning Philosophy, The Role of Government**
Practice: **Student Reports on Actors, Institutions and Laws**

Working in pairs, students should prepare a short (1 page) summary of environmental policy to date for a major medium (air, water, land, solid waste) or country (USA, Germany, Japan, England). These summaries should be handed out to the class and key points highlighted in a brief (5-10 minute) presentation.

Required Reading:

Gramlich, E.M. (1990), A Guide to Benefit-Cost Analysis, 2nd edition, Prentice Hall Inc., Englewood Cliffs NJ, pp. 9-24.

Lim, C. (1986) "Toward a Synthesis of Contemporary Planning Theories," Journal of Planning Education and Research, vol. 5, no. 2, pp. 75-85.

Mills, E.S. and P.E. Graves (1986), The Economics of Environmental Quality, 2nd edition, W.W. Norton and Co., New York, pp. 219-243 (Ch. 8: A Historical Sketch of Environmental Policy in the U.S.A.)

Portney, P.R., editor (1990), Public Policies for Environmental Protection, Resources for the future, Washington DC, pp. 7-26 (Ch. 2: The Evolution of Federal Regulation)

10/1 **Theory:** **Conceptions of Nature and Resources**
Practice: **The Adirondack Park Agency**

A variety of legislative proposals for reforming this troubled land use planning agency are circulating in the New York State Assembly and Senate. Students will be pre-assigned specific proposals, and working in small groups, during class should briefly (10-15 minutes) make the case for their proposal to an undecided legislator, and to each other.

Required Reading:

Botkin, D. (1990), Discordant Harmonies: A New Ecology for the 21st Century, Oxford University Press, New York, pp. 3-14, 133-167, 193-201, skim other chapters.

Case Study packet

McHarg, I.L. (1969), Design with Nature, Doubleday and Co., Garden City NY, pp. 103-115

Pearce, D.W. and R.K. Turner (1990), Economics of Natural Resources and the Environment, Harvester Wheatsheaf, New York, pp. 3-28 (Ch. 1).

Simpson, C.R. (1991), "Mapping the Sublime: The Social Construction of Nature in the Adirondacks," presented at the 21st Annual Meeting of the Popular Culture Association, San Antonio TX, 38 pp.

10/8 Theory: Public Participation in Environmental Decisions
Practice: Case - Hydro Quebec Part I - Aboriginal Rights and Economic Development in Canada

Locate a recent newspaper article describing a case of environmental racism or inequity, and bring in enough copies for the whole class. Be prepared to discuss the relationship between public participation mechanisms and such problems, especially in the context of the Hydro Quebec case.

Required Reading:

Canadian Federal Environmental Assessment Review Office (1988), Public Involvement: Planning and Implementing Public Involvement Programs, Executive Overview, prepared by Praxis, Inc., Calgary, Alberta, 13 pp.

Nelkin, D. (1977), Technological Decisions and Democracy, Sage Publishers, Beverly Hills CA, chapter on public participation beginning pg. 58,87 (Ch. 4).

Ozawa, C. and L. Susskind (1985), "Mediating Science-Intensive Policy Disputes," Journal of Policy Analysis and Management, vol. 5, No. 1, pg. 23-39.

Richardson, B. (1991), Strangers Devour the Land, Chelsea Green Pub., Post Mills VT, pp. ix-xiv, 132-133, 146-156, 160-164, 186-197, 224-225, 246-259- 296-361.

Steinglass, D. (1981), "Community Control in Boston and St. Paul," Shelterforce, July/August/September 1989, pp. 19-20.

Stowell, C.D. (1987) Faces of a Reservation: A Portrait of Warm Springs Indian Reservation, Oregon Historical Society Press, Portland OR, pp. xi-xii, 108-149, 183-189.

Susskind, L. and M. Elliott (1983), Pateralism, Conflict, and Co-production, Plenum Press, NY: pp. 3-31

10/15 Theory: Scientific Uncertainty and Risk
Practice: Case, continued - Hydro Quebec Part II - The New England Power Planning Game

In-Class simulation.

Required Reading

Edesess, M. and G. A. Hambrecht (1980), "Scenario forecasting: Necessity, not choice," The Journal of Portfolio Management, Spring issue, pp. 10-15.

Hanson, M.E. (1986), "Modeling for Forecasting Versus Modeling for Understanding: Observations from Energy Planning," Journal of Planning Education and Research, vol. 6, no. 1, pp. 50-59

Janssen, R. (1991), Multi-objective Decision Support for Environmental Problems, Vrije Universiteit te Amsterdam, Netherlands, pp. 17-50 (Ch. 2).

Kahneman, D., and A. Tversky (1982), "The Psychology of Preferences," Scientific American, January, pp. 160-173.

Slovic, P., B. Fischoff and S. Lichtenstein (1979), "Rating the Risks: The Structure of Expert and Lay Perceptions," Environment, vol. 21 (April).

Game Packet

Recommended Reading:

Keeney, R. and H. Raiffa (1976), Decisions with Multiple Objectives: Preferences and Value Tradeoff, John Wiley and Sons, New York, pp. 131-165.

Wang, J.L., and O. Yu (1988), "The Price of Power," IEEE Potentials, May, pp. 28-30.

Unk., The Electric Power Industry, pp. 35-ff (ch. 4, 5, 6).

10/22 **Mid-term Exam**
1 1/2 hr. closed book essay style exam during class period

Fall Recess

11/5 **Theory: Methods for Evaluating Environment Impacts**
Practice: Case, continued - Hydro Quebec Part III - The New England Project

Demonstration of interactive computer-based planning tool used in the real New England power planning debate

Required Reading:

Andrews, C.J. (1992), "Spurring Inventiveness by Analyzing Tradeoffs: A Public Look at New England's Electricity Alternatives," Environmental Impact Assessment Review, special issue on sustainability, vol. 12, no. 1/2, March/June, pp. 185-210.

Andrews, C.J. and S.R. Connors, "Existing Capacity - The Key to Reducing Emissions," Energy Systems and Policy, (1992) vol. 15, pp. 211-235.

Elliott, M. (1981), "Pulling the Pieces Together: Amalgamation in Environmental Impact Assessment," EIA Review, vol. 2, no. 1, pp. 11-37.

Gramlich, E.M. (1990), A Guide to Benefit-Cost Analysis, 2nd edition, Prentice Hall Inc., Englewood Cliffs NJ, pp. 48-78, 134-149.

Janssen, R. (1990), Multiobjective Decision Support for Environmental Problems, Vrije Universiteit te Amsterdam, Netherlands, pp. 51-90, (Ch. 3).

Recommended Reading:

Holling, C. (1978), Adaptive Environmental Assessment and Management, 1-139.

McAllister, D.M. (1980) Evaluation in Environmental Planning, MIT Press, Cambridge, MA: pp.67-171 (Ch. 5-9).

Term Paper abstract due.

11/12 Theory: Communicative Planning
Practice: Case, continued - Hydro Quebec Part IV - Revising Hydro Quebec's Approach

Hydro Quebec has requested assistance in revising its approach to resource planning. Working in small groups, students should prepare recommendations and present them briefly (10-15 minutes) in class.

Required Reading:

Andrews, C.J. (1991) "Building Consensus on a Shoestring: The Efficacy of Package Models in Joint Fact-Finding," Proceedings of the 2nd International Conference on Computers in Urban Planning and Urban Management, Oxford UK, July 8, 1991, 18 pp.

Case Study packet.

Denning, P.J. (1990), "Modeling Reality," American Scientist, 78, Nov-Dec., pp. 495-498.

Gramlich, E.M. (1990), A Guide to Benefit-Cost Analysis, second edition, Prentice-Hall, Inc., Englewood Cliffs, NJ: pp. 223-230.

Linstone, H.A. (1989), "Multiple Perspectives: Concept, Applications, and User Guidelines," Systems Practice, vol. no. 3, pp. 307-331.

Yoon, D. (1992), "Governor Cuomo's Decision to Cancel New York Purchases From Hydro Quebec," Advanced Policy Paper, MPA Program, Woodrow Wilson School, Princeton University, Princeton, NJ, 21 pp.

Recommended Reading:

Andrews, C,J, (1992) "Sorting Out a Consensus: Analysis in Support of Multi-Party Decisions," Environment and Planning and Design, vol. 19, pp. 189-204.

Ulrich, W. (1988), "Systems Thinking, Systems Practice, and Practical Philosophy: A Program of Research," Systems Practice, vol. 1, no. 2, pp. 137-163.

New England Energy Policy Council (1987), Power to Spare, Executive Summary of report, Boston, MA.

Gellings, C.W., and S.N. Talukdar (1986), "Load Management Concepts," excerpt, pp. 3-28.

11/19 Theory: Systems Thinking
Practice: Case - Industrial Ecology and Global Change Part I - The Grand Nutrient Cycles

Four major elements (carbon, nitrogen, sulfur, and phosphorus) are required by the biosphere in significantly greater quantities than they are available in nature. Human activity has altered the fluxes of all of these elements and has added significant qualities of exotic materials (such as pesticides and CFCs). A subset of students should each prepare and distribute a short (1 page) summary of our current understanding of the materials balance accounts for one of these elements or the exotics; plus present their findings briefly (10 minutes) to the class.

Required Reading:

Ayres, R.U. and R. Axtell (1992) "Industrial Metabolism and the Grand Nutrient Cycles," presented at the Global Change Institute on Industrial Ecology and Global Change, Snowmoss CO, July 19, 1992, 25 pp.

Ayres, R. (1989), "Industrial Metabolism," in Ausubel, J. and H. Sladovich, eds., Technology and the Environment, National Academy of Engineering, National Academy Press, Washington DC, pp. 23-49.

Houghton, J., Jenkins, G. and J. Ephrauns, Editors (1990), Climate Change: The IPCC (Intergovernmental Panel on Climate Change) Scientific Assessment, Press Syndicate of University of Cambridge, read the Policymakers' Summary.

Stevens, W.K. (1990), "Theory on the Number of Links in Food Chain Is Upheld in River Test," The New York Times, December 11, 1990 p. C4.

Toth, F.L. (1981), "Systems Methods for Environmental Management, Systems Practice, vol. 1, no. 2, pp. 189-216.

12/3 Theory: Regulatory Design, Industry Response, and Sustainability Criteria
Practice: Case - Industrial Ecology and Global Change Part II - Industrial Ecology

A different subset of students than those who investigated the grand nutrient cycles should each prepare a short handout and lead discussion on industrial ecology topics (specifically its characterization, manufacturing examples, influencing materials flows, constraints and incentives, education, and goals/objectives).

Required Reading:

Andrews, C.J. (1992), "Substituting Credibility for Authority in the Design of Pollution Prevention Incentives," CDCPS Working Paper, Woodrow Wilson School, Princeton University, Princeton, NJ, 20 pp.

Gramlich, E.M. (1990), A Guide to Benefit-Cost Analysis, 2nd edition, Prentice Hall Inc., Englewood Cliffs NJ, pp. 197-222.

Patel, C.K.N., organizer, "Colloquium on Industrial Ecology," Proceedings of the National Academy of Sciences, USA, vol. 89, pp.798-884, February.

12/10 Theory: Technological Optimism
Practice: Industrial Ecology and Global Change Part III - Modeling Policy Options

The final subset of students (who did not work on parts I or II) will test the IEA/ORAU Global Energy-CO2 model for the class. They should run a variety of scenarios, report the results, comment on the policy relevance of the model, and lead the class discussion.

Required Reading:

Manne, A. and R. Richels (1990), "CO2 Emission Limits: An Economic Analysis for the USA, Energy Journal, vol. 11, no. 2, pp. 51-74.

Hogan, W. (1990, "Comments on CO2 Emission Limits: An for the USA, Energy Journal, vol. 11, no. 4, pp. 35-59.

Williams, R. (1990), "Low-Cost Strategies for Coping with CO2 Emission Limits (A Critique of CO2 Emission Limits: An Economic Analysis for the USA)," Energy Journal, vol. 11, no. 4, pp. 35-59

Lave, L. (1990), "Comment," Energy Journal, vol. 11, no. 4, pp. 61-64

Perry, A. (1990), "Comment," Energy Journal, vol. 11, no. 4, pp. 65-68.

Manne, A. and R. Richels. (1990), "The Costs of Reducing U.S. C02 Emissions: Further Sensitivity Analysis," Energy Journal, vol. 11, no. 4, pp. 69-78.

Edmonds, J. and J. Reilly (1986), The IEA/ORAU Long-Term Global Energy-CO2 Model: Personal Computer Version A84PC, ORNL/CDIC-16, Oak Ridge National Library, Oak Ridge TN, pp. 261-297; scan remainder.

Schneider, S.H. (1991), "Report on Reports: Three Reports of the Inter-governmental Panel on Climate Change," Environment, vol. 33, no. 1, (Jan/Feb) pp. 25-30.

12/14 (Monday!) Summary and Wrap-Up

Term paper due on January 12, 1993.

Pollution Prevention and
Industrial Ecology
NATIONAL POLLUTION PREVENTION CENTER FOR HIGHER EDUCATION

Strategies for Environmental Management

Garry Brewer and Stuart L. Hart
CS 564/NR 513, Winter 1994
University of Michigan

CS 564/NR 513 STRATEGIES FOR ENVIRONMENTAL MANAGEMENT

Winter Term, 1994
Period 3 (January-February)
Monday-Wednesday, 8:30-10:00; Paton 1018
Monday-Wednesday, 11:30-1:00; Kresge 1310

Professor Stuart L. Hart, School of Business Administration
7209 Bus Ad, 763-6820
Dean Garry Brewer, School of Natural Resources and Environment, 764-2550

The world faces many environmental problems that originate at least in part from corporate industrial activities. Hazardous and toxic wastes created by industry are causing crises for thousands of communities around the world. Industrial accidents such as the Bhopal disaster, Chernobyl, and the Exxon Valdez oil spill, have taken heavy environmental tolls. Even more ominous, global crises such greenhouse warming, ozone depletion, deforestation, and species loss are in one way or another rooted in corporate products and production systems. While past business practices have produced tremendous economic success for some corporations and nations, the vast majority of the world lives in deepening poverty. Try as we might, it will probably not be possible to sustain 10 billion people consuming at the level of today's typical American. Over the next 20-30 years, corporations will be challenged to create new strategies rooted in the concept of environmental sustainability.

Course Description

This course is motivated by the belief that major responsibility for attacking environmental problems will fall on the shoulders of business managers. As the dominant social institutions of our time, corporations are the only organizations with the financial resources, technology, know-how, and global reach to successfully come to grips with these problems. Even now, there are observable regulatory, financial, market and social trends driving corporations toward "greening." Those that fail to recognize the significance of these trends do so at their peril. Those that understand and embrace these trends, however, will be positioned to guide their companies into the future: In the 1990s and beyond, the environment will offer business opportunities of unparalleled proportion to the early movers, and a quagmire with no escape for the laggards.

Since effective environmental management will mean learning to work with environmental groups, regulators, and other stakeholders, this course seeks a mix of students from business, natural resources, public policy, engineering and related disciplines. The first few classes in the course will be geared toward developing an atmosphere of mutual learning. Students will be divided into "maxi-mix" teams on the first day and the next two sessions will involve the science-based students in helping to teach business/policy students about ecology and business/policy students in helping to teach science-based students about strategy. Once this foundation has been established, the course will then focus directly on the challenge to business. What is the environmental challenge to business? Are economic and environmental goals necessarily trade-offs? Are there competitive benefits to moving beyond compliance? Can the environment provide a source of competitive advantage for companies? Is there a first mover advantage to be gained through an environmental strategy? What are the implications of sustainable development for the corporations of tomorrow? Through a combination of cases, readings, and lectures, class sessions will seek to engage students in discussions aimed at

developing alternative models of strategy and organization based upon the principles of environmental management and sustainable development.

By the end of the class, students should have gained a deeper understanding of the environmental challenges facing tomorrow's managers and be better prepared to evaluate alternative methods for their resolution. The course will close with a policy exercise (management simulation) on "Greening the Corporation." This exercise will enable students to practice what they have learned in a simulated corporation. It will involve students in making strategic decisions about research and development, product development, production, and marketing over a 20-30 year time horizon in a world making the transition to environmental sustainability.

Course Materials

Text: Schmidheiny, Stephan, **Changing course: A global business perspective on development and the environment.** Cambridge: MIT Press, 1992.

Coursepack: A coursepack containing readings and cases will be available in the basement sales area of the Business School.

Four additional books are highly recommended as supplemental reading and will be placed on reserve in the Business School library:

Scientific American, **Managing planet earth.** New York: Freeman and Co., 1990.

Cairncross, F. **Costing the earth.** Boston: Harvard Business School Press, 1992.

Gore, A. **Earth in the balance.** Boston: Houghton Mifflin, 1992.

Makower, J. **The E factor.** New York: Times Books, 1993.

Course Requirments

There will be two written assignments in the class. The first, a **problem definition** paper, will be an individual assignment and will require each student to define and frame an industrial problem, corporate challenge, or new business opportunity related to the environment. This one-page paper will be due 19 January. Copies will be placed on reserve and should help in forming teams for the **term project**, which will be a group assignment and will require each team to develop a case analysis on a company, industry, or industrial environmental problem. These papers will be due on 16 February. Students taking the class for 2 credits (those registered outside the business school) will negotiate a small additional writing assignment with the instructors. This might, for example, entail developing proposed solutions to the problems analyzed in the term projects.

Class participation will be a key factor in the success of the class. Given the diversity of the participants, mutual learning and teaching will be an important objective. Extensive preparation and a willingness to share knowledge and perpsectives will be critical. This will not be a course geared to "passive learning". The three components of the class-- the problem definition paper, term project, and class participation will be split equally in determining the final grade for the class. All students are also expected to participate in the policy exercise on "Greening the Corporation" the week following spring break.

Summary Outline
Strategies for Environmental Management

Wednesday, 5 January: Introduction
Reading: "Business and environment: A time for creative coexistence" (Brewer)
Monday, 10 January: Ecology
Reading: "Ecological knowledge and environmental problem solving" (NRC)
Case: Control of Eutrophication in Lake Washington
Wednesday, 12 January: Strategy
Reading: "The core competence of the corporation" (Prahalad and Hamel)
Case: Laidlaw Environmental Services
Monday, 17 January: Environmentalism and Business
Reading: "It all began with conservation" (Stenger)
Case: McDonald's Environmental Strategy (A)
Wednesday, 19 January: Beyond Compliance
Reading: "Proactive environmental management" (Hunt and Auster)
Case: Allied Signal
Monday, 24 January: Pollution Prevention
Reading: "The environmental failure" (Commoner, Ch. 2)
"Pricing the environment" (Schmidheiny, Ch. 2)
"The innovation process" (Schmidheiny, Ch. 7))
Problem Definition paper due
Wednesday, 26 January: Life Cycle Assessment
Reading: Note on Life Cycle Analysis
Case: McDonalds (B): The Clamshell Controversy
Monday, 31 January: Product Stewardship
Reading: "What does it mean to be green" (Kleiner)
"Design for environment" (Allenby and Fullerton)
"Managing corporate change" (Schmidheiny, Ch. 6)
Wednesday, 2 February: Environmental Strategy I
Reading: "Sustainable advantage" (Ghemawat)
Case: Bayerische Motoren Werke AG
Monday, 7 February: Environmental Strategy II
Reading: "Note on the structural analysis of industries" (Porter)
Case: Pacific Gas and Electric
Wednesday, 9 February: Sustainable Development
Reading: "Ecology and the politics of scarcity" (Ophuls)
"The business of sustainable development" (Schmidheiny, Ch. 1)
"The mirage of sustainable development" (Dilorenzo)
Monday, 14 February: Environmental Strategy III
Reading: "Technology cooperation" (Schmidheiny, Ch. 8)
Case: Conoco's Green Oil Strategy
Wednesday, 16 February: The Sustainable Corporation
Reading: "How green production might sustain the world" (Hart)
Case: McDonalds (C)
Term Project due

SPRING BREAK-- Monday, 21 February-Wednesday, 23 February

Policy Exercise: The Sustainable Corporation
Reading: "Methods for Synthesis: Policy Exercises," (Brewer)

Pollution Prevention and Industrial Ecology
NATIONAL POLLUTION PREVENTION CENTER FOR HIGHER EDUCATION

Environmental Science and Public Policy: Reducing Industrial Wastes

William Clark, Michael McElroy, and Robert Frosch
ESPP 98/ENR 204, Spring 1994
John F. Kennedy School of Government, Harvard University

ESPP 98 / ENR204 - Spring 1994

[LIMITED ENROLLMENT: All interested attend first session]

Environmental Science and Public Policy:
Reducing industrial wastes

T 1:00-3:00 -- Hoffman Lab Penthouse (Adjoins Peabody Museum)

Course description:

This course provides an in-depth examination of the interplay between science and public policy in society's response to environmental problems. The problem selected for extended attention this semester is the reduction of industrial wastes. The goal is to develop a systems perspective encompassing the generation and management of wastes at the regional scale, and illuminating the connections among scientific, engineering and policy dimensions of the waste management problem. The course will explore how public policy affects the development of "green designs" that reduce the generation of wastes at a process level, and of "industrial ecosystems" that find uses for the wastes that inevitably remain. Topics to be covered include historical trends in materials use, system-level inventories of industrial material flows, "green" engineering, and the impact of information, prices, regulations, and institutional design on waste reduction. Students will be exposed to readings on both the scientific and policy aspects of the cases. Several visits from industrial practitioners and a class site visit to an industrial firm dealing with waste reduction issues are planned. Perspectives from the readings, discussions and visits will be integrated through an in class cooperative policy exercise.

Prerequisites and intended audience:

This course is designed for students who wish an in-depth exploration of the interactions between environmental science and public policy. A complementary course, taught in the fall (ENR203), addresses the same issues in the context of other cases. Both courses welcome MPA and other students with broadly based experience in environmental policy. They can also serve as second-level offerings for MPP students in the School's energy and environment area of concentration. ENR 100 is normally a prerequisite for MPP students interested in either course. A background in the natural science dimensions of environmental problems is not required, although students should be prepared to read a substantial amount of science-based material. Due to the tutorial nature of the class, enrollment is limited. Interested students must attend the first class session. (This course is also offered to students of Harvard College as EPSS-98, the junior year tutorial in the Environmental Science and Public Policy Concentration. For undergraduates, ENR-100 is a prerequisite).

Requirements:

Students will be expected to read and comment on assigned materials and to participate actively in a team project. They will be asked to complete one short (ca. 2500 word) paper in the early part of the semester and one longer term paper (ca. 7500 word) due during reading period, both on topics assigned in class. Both papers will involve substantial library research. There is no examination. Reading will average about 60 pages per week. Students will be required to attend up to 4 out of class sessions involving team efforts and meetings with industry representatives. Grades will be assigned on the basis of class participation (20%), participation in the team exercise (20%), the short paper (20%) and the term paper (40%).

Readings:

Readings will consist of prepared packets sold in class.

Instructors:

William Clark (Sidney Harman Professor of International Science, Public Policy and Human Development; Director, Center for Science and International Affairs)
Room: Kennedy School L-362; Tel 495-3981; email - clark@ksgbbs
Assistant (for appointments): Nora Hickey (6-7466; email Nhickey@ksgrsch).

Michael McElroy (Abbott Lawrence Rotch Professor of Atmospheric Science; Chairman, Department of Earth and Planetary Sciences)
Room: Hoffman Lab, 4th Fl.; Tel 495-2351;
Assistant: (5-2351)

Robert Frosch (Senior Research Fellow, Kennedy School and former Vice President for Research, General Motors Corporation)
Room: Kennedy School, L-360; Tel 495-8132;
Assistant: Nora Hickey (6-7466; email Nhickey@ksgrsch)

ESPP98 / ENR204 - Spring 1994

Environmental Science and Public Policy:
Reducing industrial wastes

T 1:00-3:00 -- Hoffman Lab Penthouse (Adjoins Peabody Museum)
[LIMITED ENROLLMENT: All interested attend first session]

Syllabus (January 25, 1994)

1 Introduction to the course

Outlines the objectives, approach and expectations of the course. Sketches a framework for analysis of public policy interface with technical dimensions of waste production and management. Substantive discussion focuses on a number of paradoxes of waste reduction efforts, summarized in a handout.

Part I: Science and engineering issues

2 Waste production: An overview

Provides an overview of the waste production problem, distinguishing flows associated with raw material acquisition, industrial production, and end use consumption. Introduces typology of recoverable vs dissipative material flows. Illustrates trends with time, and across countries.

3 Waste flows from a product life cycle perspective: The case of the modern automobile

Examines the material flow, waste and recovery streams inherent in production and use of the automobile. Case selected as an illustration of a relatively well-integrated product cycle in which a high fraction of wastes have either been eliminated through green design or are recovered for reuse.

4 Waste flows from a regional perspective: The case of cadmium in the Rhine Basin

Develops a systems perspectives on the multiple sources, pathways, and sinks for a single industrial chemical (cadmium) in a large river basin. Traces changes through time on the relative importance of production- and consumption-related sources of the waste stream.

Part II: Policy Perspectives

5 Economic dimensions of industial waste reduction

Examines the economic dimensions of the industrial waste problem. Includes discussion of relative costs of alternative waste reduction, disposal, and recycling technologies, pricing of externalities associated with waste, and impact of on waste treatment of liability rulings.

6 Legal and regulatory dimensions of industrial waste reduction

Explores the impacts of alternative legal definitions of industrial wastes and hazards. Considers the unintended consequences of current regulations for industrial ecology.

7 Organizational intelligence for waste reduction

Considers the role of information and non-economic incentives in waste reduction. Special attention paid to the utility of regional electronic "clearing houses" for waste producers and users, such as proposed by the Chicago Board of Trade. Looks at role of accounting and reward structures within corporations for encouraging innovations in waste reduction.

Part III: A field study in industrial waste reduction

The class will study in depth the waste management problems and prospects of a major manufacturing company in the Boston area. The study will involve a visit to the company, as well as discussions with key staff.

8 Introduction to wastes in the XX Company

Senior official from XX provides an overview of waste problems and management efforts at the Company.

9 Site visit to XX Company

Class visits XX, observes general flow of materials, conducts small group interviews with relevant officials concerning efforts at, opportunities for, and obstacles to waste reduction.

10 Analysis of site visit experience

Student teams report on data gathered on Company XX. Class discussion of prospects for improvements, plus relative importance of economic, regulatory, information barriers to improvements in performance.

Part IV: A Massachusetts Commission on Industrial Waste Reduction

The major class exercise will be a simulation of a governor's advisory commission on public policies to enhance waste reduction in Massachusetts' industries. Class members will be broken into groups and given their charge as commission members early in the term. Subsequent meetings, in and out of class, will pave the way for presentation and discussion of the commission's findings.

11 Presentation of Commission findings in class

Teams will present their findings to the class and answer questions from a panel of critics.

12 Retrospective on Commission findings and the prospects for reducing industrial wastes.

Pollution Prevention and Industrial Ecology
NATIONAL POLLUTION PREVENTION CENTER FOR HIGHER EDUCATION

Proposal for a Curriculum in Ecological and Development Economics

Faye Duchin
March 1993
New York University

Revised
March 1993

Proposal for a Curriculum in Ecological and Development Economics

by

Faye Duchin, Director*
Institute for Economic Analysis
New York University

At the 1992 meeting of the International Society for Ecological Economics (ISEE) in Stockholm, I chaired a round-table session on curriculum development. The panelists included individuals who already offer, or who are planning, a degree program in Ecological Economics (EE). In addition, we benefitted from an unusually high level of engagement on the part of the audience (perhaps 60 people). Consequently, a clear picture of the present state of curricula in EE emerged.

There is enormous diversity in what is being considered the content of EE for purposes of curriculum development; some situate it within the scientific tradition while for others it is part of the liberal arts. It is too early for ISEE to try to standardize one or more curricula or even to play a quality-control role of selectively accrediting certain programs but not others because there is simply not yet enough organized material available. But it is indispensable to create, and teach, a few exemplary curricula that will have the important secondary purpose of providing models that can be used and customized by our membership.

While practically all members of ISEE recognize its importance, economics does not play a central role in many of these curricula. Furthermore, the part of economics which does serve as a common denominator is related more to valuation problems and discount rates than to strategies for economic development. The purpose of this proposal is to develop a model curriculum for Ecological and Development Economics (EDE). EDE is intended as a variant of EE which is rooted in economics. The proposal is divided in three sections. The first describes common problems of existing curricula, the second describes the challenges of designing a new curriculum and how I propose to address them, and the last section contains a description of the proposed curriculum itself.

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* Faye Duchin is also Vice President for Education and Membership of the International Society for Ecological Economics and chairs its Committee for Curriculum Development.

I. Common Problems of Existing Curricula

There is an enormous amount of activity and enthusiasm surrounding curriculum development in EE. Experience at a number of institutions suggests that the student demand for such programs is substantial. However, certain problem areas are also apparent. These are the more troublesome because they are generally not directly acknowledged and addressed in the design of new curricula.

A. Background of Students

Most of the graduate-level programs that were discussed in Stockholm are intended to accept students with virtually any background. This decision is desirable in that it will increase the number of potential students and assure a mix of interests and backgrounds. Unfortunately, however, it also precludes in-depth treatment of any subject except on an entirely individualized basis which is not practical for training significant numbers of students.

Today, virtually all economics departments in US universities offer the same curriculum in neoclassical economics. I believe that we should not follow this lead in EE but should develop diverse curricula, each deeply grounded in a subset of the problems we face. Existing curricula attempt to provide all things to all potential students, but most EE students will benefit from more focus and depth in their training. The curriculum proposed here is grounded in economics.

B. Role of Mathematics

The programs in existence or preparation do not take a position about which requirements in mathematics students of EE will be expected to satisfy. Consequently, each of these programs will prepare students with varying amounts of exposure -- including none -- to the different fields of mathematics. Except in cases where EE is taught strictly within the humanities, I believe that specific requirements in mathematics are needed. Mathematics has revolutionized all of the sciences, and our students should be encouraged to benefit from the potential power of its application to understanding and resolving problems. One of my objectives in this proposal is to develop guidelines on this subject by reasoning from the content of the program to the mathematics, and statistics, which are appropriate for handling it.

There is a tendency in some quarters to de-emphasize a systematic approach to quantitative methods in EE training for several reasons. Because of the importance of social values and of

action to EE and because not even the entire descriptive framework of EE is yet complete, some feel that quantitative methods are less important than teaching students to "ask the right questions," at least at this time. Others are disposed to de-emphasize quantitative methods because they are frequently misused and abused. While there is truth in both positions, I am convinced that quantitative methods need to play a central role in EE for the following reasons.

The effective manipulation of numbers and symbols is needed whenever it is necessary to achieve a quantitative result (e.g., what is likely to be the evolution of carbon dioxide emissions over the next 50 years if we do not take special actions to curtail them?) Ecological economists need to understand these techniques if they are to identify questionable uses of them. But the most important reason is that at least some ecological economists will need to master these techniques in order to <u>use</u> them constructively, and this proposed curriculum is aimed at these individuals. The challenges are to be selective in what we teach and to teach about quantitative methods in conjunction with real applications.

C. Building on Existing Courses

Many programs are built on the basis of existing courses in economics, ecology, marine sciences, etc, to which they add one or two synthesis courses. For example, the program may accept for credit, or even require, courses in neoclassical microeconomics and macroeconomics taught by instructors in the economics department. This way of proceeding to build an EE curriculum has practical advantages; it makes it possible to build a program quickly and to offer it within an existing departmental structure. The accompanying synthesis courses then need to put these existing courses into EE perspective.

The problem is that this, of course, is difficult to do when the courses are basically business as usual. Consequently, the synthesis courses risk ending up as a set of relatively superficial surveys and critiques. The resulting EE curriculum may be hard to distinguish from an environmental economics curriculum based on neoclassical economics alone.

Explicit design of EE courses, within a coherent curriculum, will be indispensable if EE is to have an identity and to provide students with conceptual and practical tools for EE analysis. Adequate resources will need to be earmarked for the development of a curriculum that is able to take on this challenge.

D. Pitfalls of Survey Orientation

Most EE curricula are conceived as survey exposures, from a pluralistic point of view, to several disciplines. They are broad rather than deep; they emphasize avoiding dogmatism and asking the right questions. Reading lists are also of a survey nature and not, in my opinion, sufficiently discriminating.

This approach has emerged as the first stages of building EE, and every program will have to include an introductory survey-type exposure to the problems. However, this will not be adequate to provide the basis for scientific or policy work designed to ask the big questions: What needs to be done? How can we do it?

II. Challenges of Designing a New Curriculum

Instruction in a substantially new new field requires the development of a new curriculum. This requires designing both new content and new institutional arrangements. Such an effort will inevitably run into opposition because of various customs and vested interests.

In a "mature" field, by contrast, existing courses are periodically brought up to date and the textbook may be changed from time to time. Occasionally, courses may be added to or deleted from the curriculum. In most disciplines, virtually the same curriculum is taught at all, or at least all major, universities. Mainstream economists today perceive the need for marginal changes to this common curriculum but certainly not for a new curriculum.

The question arises as to whether Ecological Economics is a new field. Some feel that EE is simply a sub-discipline of neoclassical economics. In this view, a few new courses added to the standard neoclassical curriculum are adequate to train students of economics in Ecological Economics.

It is my view, however, that EE needs to be substantially different from existing programs in the conception of educational and training programs. EE makes use of the thought and analysis of past generations of economists but follows a particular set of branches through the family tree. EE places far more importance on values and social objectives, on the relation between human activities and the natural world, and on the importance of assorted institutional actors. EE will tolerate, in fact encourage, diverse curricula being taught at different institutions.

A. Need for a Team to Build the Curriculum in Ecological and Development Economics

The curriculum needs to be developed by a team of academics -- but not "by committee." While one person cannot be expected to develop the curriculum to the point of providing detailed readings in all areas of what is in fact a very broad new field, it is important that the curriculum have coherence and not become simply a collection of classes about interesting topics chosen by vote or consensus. I believe that the proposed curriculum has this coherence, and I am able to assemble a team of motivated and highly competent economists and others to refine and develop it.

I will be able to draw on the members of the ISEE Curriculum Committee, which I chair, and to try to conduct this project like a seminar intended to advance all of our thinking on the subject of EE.

Since this is an economics curriculum, most of the team members will naturally identify as economists. However, it is important to include a few other experts, (e.g., in mathematics and statistics or in ecology). These individuals cannot be expected to have the same motivations as the economists in the team; they need to be paid for their time accordingly. They need to commit to participate in all the meetings, for their subjects have to imbue every course and not be add-ons.

Our students will need to learn the principles of ecology. However, until there is new curriculum design in ecology -- parallel to what is here proposed for economics -- it is difficult for us as economists to achieve a profound integration of ecology into our curriculum. We will include one or more ecologists on our team, and we will use readings about the eco-system in many of the courses when relevant material can be identified. At a later date, it will surely be possible to go even further. But this situation will need to evolve, and there is an enormous amount of groundwork that needs to be laid in the meantime.

While ISEE includes policy analysts and activists as well as academics, I believe that the perspective, teaching experience, and detachment of academics is needed for this stage of the work. These must be academics who give priority to the needs of policy and action.

B. Creating an Institutional Base

The most suitable and convenient place to offer this curriculum is at a university, and I believe (based on various types of experiences) that the proposed curriculum would be

attractive to many students. The problem is that economics departments will not be in the market for replacing their own curriculum.

The adoption of an entire EE curriculum is possible in the following cases:

. Schools of public policy cut across conventional disciplines. Some technical institutes have a single department of social sciences and no separate economics department. In these kinds of multi-disciplinary environments, there is likely to be support for an EE curriculum.

. Given the virtual certainty that environmental concerns will transform today's curricula in several fields (not just economics), some pioneering university administrators will be prepared to support experiments.

. In a university not competing to be in the "top tier," the economics department might be favorably disposed to adopting such a curriculum itself. This is particularly true outside the US.

. It may be possible to organize an innovative consortium of universities to give credit for a joint program. I have begun to explore this option.

Once we can display a fully developed curriculum to demonstrate what we intend to do, it will be much easier to win the administrative battles.

III. Outline of Proposed Curriculum

A. General Considerations

For the curriculum proposed here, incoming students need to have the equivalent of an undergraduate exposure to economics or to be sufficiently motivated to compensate for this (as they would in any Master's program in economics). They will be exposed to concepts and facts about the workings of an economy and the associated pressures on the environment, as well as to analytic methods for evaluating alternative ways to proceed, and will leave trained as Ecological and Development Economists (a type of economist).

Students completing the degree should be able to go on to a doctoral program in EE (which should be the next step in our curriculum development process) or else simply in economics (for example, environmental economics). Many students, in all fields, receiving academic Master's degrees do not go on for a doctorate,

and this will surely be true in EE as well. Since EE is more oriented toward real problems than many academic disciplines, an emphasis will be placed on the use of practical materials in all courses.

Conventional economists, including academics, frequently serve as advisors to government officials and corporate executives. Ecological Economists are likely also to play a leading role in non-profit institutions of many sorts. The individual trained in the proposed curriculum will have a broad understanding and a long-term vision as well as a familiarity with the pressing problems. Some will be attracted to dealing with immediate crises and others will hopefully be more involved in strategy.

A question arises about whether or not the curriculum should include separate courses in values and ethics, as is now the practice in many business schools. We believe that these issues need to be incorporated throughout the curriculum. Because our economics is not based on the unique mechanism of the optimization of individual, short-term benefits, we will in fact be required to consider a range of social values in all courses.

The outline in the next section is intended as a Master's-level program. Individual courses can also be used for the ISEE certificate Program or in other settings. This outline also provides the basis for a more extensive and in-depth PhD program, and the same ideas can be developed for an undergraduate program.

B. Proposed Curriculum

1. Introduction to Ecological and Development Economics (EDE)

This course will describe the scope and problem-orientation of the field and the roles of qualitative and quantitative analysis in EE. A brief comparison with the field of neoclassical economics will be offered, and the classics of EE (Daly, Costanza, Funtowicz, etc.) will be assigned.

2. Macroeconomics (fresh version)

This course is about the overall evolution of a nation's economic activity in terms of total income, consumption, employment, the price level and the other "macro" variables. The emphasis will be not on "growth" but on structural change, on the incorporation of subjects not usually emphasized in macroeconomics like demographic change, and on the relation between the subject matter of this course and the underlying technological and social reality. Macroeconomic policies will be compared with other kinds

of actions that a government, and its citizenry through social institutions, may take.

3. Microeconomics (fresh version)

This course is about consumers, producers, and owners of resources. It will shift the usual emphasis of microeconomics from the behavioral decisions made by individuals toward the material circumstances of their everyday activities; this will serve as a natural introduction to the sources of environmental degradation. The interactions among these categories of actors will be described without extensive reliance on the devices of equilibrium and optimization and with a realistic appraisal of the role of markets.

4. Input-Output Economics and Scenario Analysis

This course is about consumers, producers, and owners of resources viewed not as individuals but grouped into sectors that are relatively homogeneous in terms of their economic activities and their use of the environment. Each sector is described in terms of its inputs and outputs of raw materials, material goods, services, employment of workers with varying skills, and its impact on the environment. Input-output analysis makes it possible to bridge the usual concerns of macroeconomics and microeconomics through its representation and analysis of the interdependency of the different sectors of the economy. The course will focus on the use of this approach to analyze future-oriented and action-oriented scenarios for sustainable development and the need to supplement quantitative results by qualitative assessment of their implications. Alternative scenarios replace the unique and "optimal" solutions of neoclassical economics.

5. The Evolution of Economic Thought and Analysis

The political economy of the pre-marginalist economists and of the structuralist development economists provide a sound basis for EDE. The contribution of the institutional economists is also important for EDE, but it has had relatively little influence on the modern mainstream because it has remained exclusively qualitative. As a formal framework capable of yielding quantitative results, the modern tradition of input-output analysis -- a fundamental generalization of cost/benefit analysis -- is important for EDE as it avoids many of the pitfalls of general equilibrium theory and provides the basis for linking the economy and the natural world.

6. Technology, Households, and Institutions

The scope of EDE has to be broad enough to include real substance about technological choices for activities like preparing food or making steel; the activities of different types of households such as their use of automobiles, common transport, or bicycles; and the roles of social institutions other than markets. These will be studied in concrete detail for different regions of the world economy, qualitatively and where possible quantitatively.

7. Natural Resources and the Pollution of Air, Land, and Water

Economic activities require materials, fuels, water, air, and so on, and generate wastes. This course will examine the resources and wastes associated with different technologies and institutional arrangements and the possibilities for resource-saving, pollution-reducing substitutions that might be associated with economic incentives or legislated requirements.

8. Economics of Sustainable Development

This course will focus on economic development, from a global perspective, and how it could be "sustainable." The concepts of growth, improving the material standard of living, quality of life, sense of community, and other possible criteria will be considered. Case studies will cover the experience in recent decades in different regions of the world.

9. The Effective Use of Cost and Benefit Evaluations

Cost/benefit analysis has become a standard technique for evaluating projects that have both economic and environmental impacts. This approach will be taught through the use of selected case studies that illustrate its power as well as its limitations. The latter can be largely overcome but at the cost of an analysis that is more complex both to carry out and to explain to those who will ultimately make use of the outcome.

10. Scenario Analysis: The Future of the World Economy

EDE takes a future-oriented and action-oriented perspective toward solving global and local problems, opting for the formulation and analysis of various, alternative ways to proceed in the place of the unique, "optimal" solutions of neoclassical economics. While the alternatives can and should be subjected to analytic scrutiny, the choice among the alternatives is understood

to be made in the social and political arenas. In this course scenarios will be formulated in terms of concrete technological and institutional alternatives in such a way as to make possible comparative quantitative and qualitative assessment and to provide a basis for action.

11. Legislation and Policy Instruments

This course will survey the kinds of instruments available for guiding economic activities so as to alleviate environmental degradation and assess their short-term and long-term effectiveness. Global and multi-lateral agreements, as well as examples of national and subnational legislation, will be included.

12. Mathematics and Statistics for EE

For this phase of development of the curriculum, we will need to rely on existing courses in mathematics (like operations research) and statistics. A graduate-level course in descriptive statistics and statistical inference will be suitable for our purposes. Students will also learn to use computer graphics and thematic mapping for the effective analysis and presentation of information. (The other courses -- micro, macro, input-output, and cost/benefit -- will need to be largely self-contained in terms of mathematics.)

13. Research Seminar/Policy Seminar

The research and policy seminars are the capstone events of this program. The purpose of the research seminar is to give students the opportunity to select a research topic, present their work at different stages of preparation, to critique each other's work, and to learn to identify the kinds of assistance they need to carry out a multi-faceted analysis. In most cases, the topic will combine both the articulation of a conceptual framework and an empirical investigation. The policy seminar is more sharply focused on addressing timely problems in their institutional settings and offers similar opportunities for critique and feedback.

The objective of this project for curriculum development is to have a group of motivated Ecological Economists revise the list of courses and make significant progress in the design of each course, with all of the courses developed to the point where they can be taught after the first year's work. The team will prepare a manuscript of its work for wide distribution at the end of a year;

this manuscript can be expected to be an invaluable aide to the EE community. Individual members of the team will be prepared at that time to actually offer these courses when the degree program is offered for the first time. A faculty training seminar should be held at the end of the year.

In parallel with this curriculum development effort, the team members will be working to secure commitments to the Consortium that will first offer this curriculum. The second-year and third-year budgets contain the salaries for instruction for the 2-year duration of the Master's program. It is anticipated that the universities will pick up the costs of instruction following this initial offering.

John F. Kennedy School of Government,
Harvard University,
Spring, 1995.

ENR-204/ESPP-90A: INDUSTRIAL ECOLOGY and GREEN DESIGN

SYLLABUS: 01/18/95

Course Objectives and Structure

This course provides an in-depth examination of the emerging field of Industrial Ecology; a systems view of the flow of materials through industry. The course investigates how government policy, looked at from a systems perspective, could affect public and private initiatives to achieve efficient reductions in the net wastes of the industrial system through the more efficient use of materials including the reuse of industrial "wastes" and products at the end of their useful lives as feedstocks. Policy issues which bear on the ability of the industrial system to adapt to a more ecological approach - technology, economics, information, regulation, the law and organization - are considered in order to understand better the extent to which they act both as incentives and as barriers to innovation. Drawing on case materials and site visits, class members will participate in exercises designed to develop an understanding of the systems approach to problem-solving generally and to waste minimisation in industry particularly. Changes in approach to the design and implementation of public policy that might lead to a better integrated industrial ecology will be an important focus of the seminar.

Intended Audience and Prerequisites

The course is intended primarily for Kennedy School students, including MC/MPA's, and students of Harvard's professional schools who have broadly based experience in environmental policy. It is also offered as a junior year tutorial (ESPP-90A) to students of Harvard College concentrating in natural sciences and environmental studies.

The class will be taught as a seminar/tutorial. Students should be prepared to participate in class discussions, group tasks and for two site visits, one of which will be a day-long visit to a foundry.

ENR-100 is a prerequisite for undergraduates and MPPs wishing to enroll.

Pollution Prevention and Industrial Ecology
NATIONAL POLLUTION PREVENTION CENTER FOR HIGHER EDUCATION

Industrial Ecology and Green Design

Robert Frosch, William Clark, and Michael McElroy
ENR 204/ESPP 90A, Spring 1995
John F. Kennedy School of Government, Harvard University

Enrollment is limited to twenty students and by permission of the instructors. No auditors.

All students who wish to be considered must attend class on February 6.

Students wishing to enroll must attend class on February 6 and submit a personal data sheet by 4.30 pm, Monday, February 6, 1995. Please put this in Jan Crawford's mailbox opposite Room L362 in the CSIA, KSG. This one-page summary should set out the student's full name, contact information (including email address), confirmation of compliance with prerequisites [ENR-100 for MPPs and Harvard College students], any relevant courses completed, training and work experience, together with a brief statement of what the student wants out of the course and what (s)he would bring to it. The final class list will be posted on Dr Frosch's door at midday, Tuesday, February 7, 1995. A copy of the list will be sent directly to everyone who supplies an email address.

Please note: "Shopping" day is Wednesday, February 1, 1995 and the first formal class is Monday, February 6, 1995.
[Venue: May differ from scheduled class meeting.
Call Nora O'Neil, Ph. 496-7466 for details]

Kennedy School students take particular note: No class is scheduled for Friday, February 3, 1995.

Class Meetings

Monday and Wednesday, 2:30 - 4:00 PM, in Belfer Room 124

Shopping day:	Wednesday, February 1. Prospective students welcome.
First formal class:	Monday, February 6.
Principal Instructor:	Dr. Robert A. Frosch Kennedy School of Government Littauer Room 362 Ph (617) 495 8132 Fx (617) 495 8963 <frosch@ksgbbs.harvard.edu> Mailbox in CSIA, opposite Rm L362 in KSG
Office hours:	See sign up sheet on office door or make an appointment by calling Jan Crawford.

* Memo on scrap yard due: Wednesday, March 22, 1995
* Memo on foundry due: Wednesday, May 3

3. Major exercise (in three parts)

   This exercise combines an individual paper with a group task, laying the foundation for an individual final paper designed to synthesize the course learning.

Individual paper due:	Monday, April 24
Group presentation:	Monday, May 1
FINAL individual paper:	Monday, May 22

All papers, except the final, to be submitted in class.

Grading

Systems paper	10%
Memo on scrap yard visit	5%
Memo on foundry visit	5%
Individual paper	10%
Group task	20%
Final paper	30%
Class participation:	20%

Late papers will not be accepted unless the prior permission of the instructor has first been obtained.

Course Materials

Many of the course reading materials will be available in course packets from the Kennedy School CMDO. In addition, the following books are recommended for purchase and will be available in class. Jan Crawford will handle purchases. Please bring your payment to one of the first three classes. Checks should be made out to Harvard University. If you pay by cash, the correct amount would be appreciated. Credit cards cannot be accepted.

1. Allenby, B.R. and D.J. Richards, Ed. (1994). The Greening of Industrial Ecosystems. Washington, D.C., National Academy Press.

   Price: $27.00

   The list price of this text is $34.95

2. Office of Technology Assessment, (1992). Green Products by Design: Choices for a Cleaner Environment. No. OTA-E-541, U.S. Congress, Office of Technology Assessment.

   Price: $6.50

Total amount: $33.50

To be distributed in class (no charge):

1. Richards, D.J. and R.A.Frosch, Ed. (1994). Corporate Environmental Practices: Climbing the Learning Curve. National Academy of Engineers, National Academy Press, Washington, D.C.

2. Richards, D.J. and A.B.Fullerton, Ed. (1994). Industrial Ecology: U.S./Japan Perspectives. National Academy of Engineering, National Academy Press, Washington, D. C.

Optional readings may be placed on reserve in the KSG library.

ENR-204/ESPP-90a: Class Schedule (01/18/95)

SHOPPING DAY: WEDNESDAY, FEBRUARY 1, 1995.
Dr. Frosch speaks for 30 mins at 2:35 PM and 3:20 PM.
[Venue: May differ from scheduled class meeting.
Call Nora O'Neil, Ph. 496-7466 for details]

Students wishing to enroll must attend class on February 6 and submit a personal data sheet by 4.30 pm, Monday, February 6, 1995. Please put this in Jan Crawford's mailbox opposite Room L362 in the CSIA, KSG. This one-page summary should set out the student's full name, contact information (including email address), confirmation of compliance with prerequisites [ENR-100 for MPPs and Harvard College students], any relevant courses completed, training and work experience, together with a brief statement of what the student wants out of the course and what (s)he would bring to it. The final class list will be posted on Dr Frosch's door at midday, Tuesday, February 7, 1995. A copy of the list will be sent directly to everyone who supplies an email address.

Venue: Belfer Room 124

<u>INTRODUCTION & CONCEPTS</u>

1. Introduction - Overview of Industrial Ecology
   Monday, February 6

2. Introduction to Green Design
   Wednesday, February 8

3. Introduction to Systems Concepts
   Monday, February 13

* **"Systems" exercise introduced (due Monday, March 6).**

4. Introduction continued - includes commentary on the concepts and theory of Ecology as they relate to Industrial Ecology and Green Design.
   Wednesday, February 15

PRESIDENT'S DAY: MONDAY, FEBRUARY 20

AN 'IDEAL' SYSTEM STATE?

5. Implementing Industrial Ecology ideas locally - Kalundborg and other "industrial park" cases
Wednesday, February 22

Guest speaker: Nicholas Gertler
Technology, Business & Environment Program, MIT.

PROBLEM BOUNDARIES & SCOPE

6. Materials and Waste Flows
Monday, February 27

7. Regulatory & Policy Framework
Wednesday, March 1

* **Major exercise introduced**
This exercise combines an individual paper with a group task, laying the foundation for a final paper which will require each student to synthesize the course materials, site visits and class work into policy recommendations for the implementation of industrial ecology.

Individual papers due: Monday, April 24
Group presentation: Monday, May 1
Final individual paper: Monday, May 22

ANALYTICAL FRAMEWORKS

8. Life Cycle Assessment - Car recycling as a successful case
Monday, March 6

* **First "systems" paper due.**

9. Scrap yard visit
Wednesday, March 8

* **Memo on site visit to be prepared (due Wed, March 22).**

10. Industrial Metabolism - Cadmium in the Rhine
Monday, March 13

* **First exercise returned**

11. The Ecology of Metals - Recycling Copper and Silver
Wednesday, March 15

PUBLIC POLICIES AND THEIR USES IN INDUSTRIAL ECOLOGY

12. Economic mechanisms and policy for industrial ecology
    Monday, March 20

13. Law - Overview of U.S. environmental laws from the perspective of the firm
    Wednesday, March 22

MIDTERM BREAK: MARCH 25-APRIL 2

14. Resource Conservation and Recovery Act/Superfund - Definitions of waste, liability, and other compliance issues and their impact on industrial systems
    Monday, April 3

* **Scrap yard memos returned.**

15. Information and its influence on the industrial system and company practice
    Wednesday, April 5

* **Major exercise reviewed.**

16. Information - The need for technical assistance to small firms
    Monday, April 10

    Guest speakers from Mass. Office of Technology Assistance

FIRM BEHAVIOUR

17. Inside the Company - Managing environmental compliance.
    Wednesday, April 12

    Guest speakers from industry

18. Foundry visit - Background to field trip
    Monday, April 17

19. Foundry visit
    Wednesday, April 19

* **NB: This will be a one-day trip (probably 8am - 4pm)**

* **Memo on site visit to be prepared (due Wed, May 3)**

INTEGRATING IDEAS & CONCEPTS

20. Public Policy for Industrial Ecology and Green Design
    Monday, April 24

* **Individual papers prepared as part of major exercise due.**

21. Ideas for Public Policy
    Wednesday, April 26

22. Group Presentations - Major Exercises
    Monday, May 1

23. Summary and Review of Class Exercise
    Wednesday, May 3

* **Memo on Foundry visit due.**

READING PERIOD: MAY 6-17

FINAL EXAMS: MAY 18-27

FINAL PAPER DUE: 4:00 PM, MONDAY, MAY 22, 1995
ROOM BELFER 307

Research Associate: Jan Crawford
Kennedy School of Government
Belfer 307
Ph (617) 496 6218
<crawford@ksgbbs.harvard.edu>
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Co-instructor: Professor William C. Clark
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Littauer Room 360
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Faculty Assistant: Nora Hickey O'Neil
Kennedy School of Government
Littauer Room 364
Ph (617) 496 7466
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<noneil@ksgrsch.harvard.edu>
Mailbox in CSIA opposite Rm L362 in KSG

With participation of: Professor Michael McElroy
Hoffman Laboratory, 4th Floor
Ph (617) 495 2351
<mbm@io.harvard.edu>

Course requirements

In addition to reading, class attendance, and well-prepared constructive participation in class discussion, students will be required to complete five pieces of written work, participate in a group presentation and attend two pre-arranged site visits. Some exercises will be undertaken in groups.

1. Students, possibly working in groups, will prepare a written paper (about 4-6 pages single-spaced) demonstrating concepts of the systems approach to framing an issue.

* Paper due: Monday, March 6, 1995.

2. Each student will prepare two short memos (about 2 pages single-spaced) recording the site visits.

Pollution Prevention and
Industrial Ecology
NATIONAL POLLUTION PREVENTION CENTER FOR HIGHER EDUCATION

Industrial Ecology: Theory and Practice

Gregory A. Keoleian
SNRE 501, Winter 1995
University of Michigan

INDUSTRIAL ECOLOGY: THEORY AND PRACTICE
SNRE 501 Section 003
Winter Term 1995

Syllabus

Time	3:00 - 4:30 Monday and Wednesday
Location	1520 Dana Bldg.
Instructor	Dr. Gregory A. Keoleian (Greg) Assistant Research Scientist Manager, National Pollution Prevention Center
Office	2506 A Dana Bldg. School of Natural Resources and Environment
Phone	764-3194
E-mail	gregak@umich.edu
Office Hrs	to be announced
Teaching Assistant	Mr. Jonathan Koch
Secretary	Ms. Kathy Hall
Office	2544 Dana Bldg.

Course Background

This course was first offered last winter term as part of an education/research project, entitled "Interdisciplinary Education and Research on Industrial Ecology." Support for developing and teaching the course was provided through the AT&T Foundation's Industrial Ecology Faculty Fellowship Program. This grant was renewed for a second year, which will provide fellowships for both Dr. Keoleian and Professor Jonathan Bulkley, Director of the National Pollution Prevention Center (NPPC) based at the School of Natural Resources and Environment Educational resources identified in the course will be incorporated in an industrial ecology compendium which will be disseminated to universities nationwide.

Course Description

Industrial ecology is a newly emerging conceptual framework for understanding the complex relationships and interactions between industrial activities, the environment, and societal needs. This framework guides the identification, evaluation, and reduction of adverse ecological and human health effects associated with both industrial processes and their products. Industrial ecology which is rooted in systems analysis offers a framework for studying our technologically-based society in an ecological context. "Industrial metabolism" is defined by the flow of material and energy through a product life cycle. This life cycle encompasses raw materials acquisition and processing, manufacturing, use, resource recovery, and the ultimate disposition and fate of residuals.

Successful application of industrial ecology principles requires multi-disciplinary perspectives and cooperation. To address this need, the course will be designed as an interdisciplinary course and recruit students from a broad base including SNRE, engineering, business, industrial design (School of Art), and public health. The course

will focus both on the theory of industrial ecology and its practical applications. Ecological, economic, social, political, and technological perspectives will be considered.

Course Content

The theoretical component of the course will draw principally from a series of papers presented at a National Academy of Sciences Colloquium on Industrial Ecology and research conducted as part of the AT&T Fellowship. Because industrial ecology is a relatively new framework there will be many opportunities for the class to critique and help shape this framework.

The course will provide you with practical tools and methods for implementing principles of industrial ecology. The practical applications covered in the course will be based largely on research activities in the area of *life cycle assessment* (LCA) and *life cycle design* sponsored by the US EPA. Life cycle assessment is a comprehensive tool for identifying and evaluating the full environmental burdens associated with a product system from production through retirement. This methodology can be used for comparative analyses of product alternatives such as disposable and cloth diapers, or paper, plastic and ceramic cups. Life cycle design also referred to as Design for Environment (DFE) focuses on integrating environmental considerations into product design. The challenge is to meet performance, cost, legal, and cultural requirements while achieving environmental improvements.

Course Format

Concept, principles and methodologies will be introduced by lecture and discussed in a seminar format. Case studies will be used throughout the course to demonstrate concepts and principles and highlight accomplishments and practical limitations of the life cycle assessment and life cycle design.

Course Resources

1. Course pack: available at Dollar Bill

2. Keoleian, G., Koch, J., Menerey, D. and Bulkley, J. Life *Cycle Design Framework and Demonstration Projects: Profiles of AT&T and AlliedSignl,* Cincinnati, OH: U.S. EPA, Office of Research and Development, Risk Reduction Engineering Laboratory, January 1995 (Draft Report).

3. Keoleian, G. and Menerey, D. *Life Cycle Design Guidance Manual: Environmental Requirements and the Product System. (EPA/600/R-96).* Cincinnati, OH: U.S. EPA, Office of Research and Development, Risk Reduction Engineering Laboratory, January 1993.

4. Reserve Textbooks at the Natural Science Library

   a. *Ecology and Our Life-Support Systems* Odum, Eugene P., Sinauer Associates, Inc.: Sunderland, Massachusetts.1993.

   b. *Industrial Ecology* Graedel, T.E.and Allenby, B., not yet published, uncorrected pageproof.

   c. *Green Products by Design: Choices for a Cleaner Environment* (OTA-E-541) U.S. Congress, Office of Technology Assessment (1992).

d. *The Greening of Industrial Ecosystems* National Academy Press: Washington, D.C. (1994).

e. *Life Cycle Assessment: Inventory Guidelines and Principles (EPA 600/R-92/245).* Cincinnati, OH: U.S. EPA, Office of Research and Development, Risk Reduction Engineering Laboratory, February 1993.

Course Outline

I. Introduction

Jan.9 Overview of the Course: Industrial Ecology - Systems Framework
- Material and Energy Balances
- A Framework for Sustainable Development
- Interdisciplinary Approach

Reading: Jelinski, L. W., T. E. Graedel, R. A. Laudise, D. W. McCall, and C. Kumar N. Patel. "Industrial Ecology: Concepts and Approaches." *Proceedings, National Academy of Sciences, USA* 89 (February 1992): pp. 793-797.

Jan. 11 Overview of Environmental Problems: Global, National, Local Perspectives
- Energy
- Resource Depletion
- Solid Waste
- Hazardous Waste
- Toxics Release Inventory (TRI)
- EPA Relative Risk Study

Reference: *Overview of Environmental Problems* (1994) Draft, National Pollution Prevention Center.
Limits to Growth (1972) Meadows, D.H. et al.
Beyond the Limits (1992) Meadows, D.H. et al.
Reducing Risk: Setting Priorities and Strategies for Environmental Protection, U.S. EPA SAB-EC 90-021

Jan. 18 Overview of Environmental Problems (continued)

II. Industrial Ecology: Theory

Jan. 23 Industrial Ecology: An Emerging Field of Ecology?
- Definitions
- Historical Perspective
- Fields of Ecology

Reading: Allenby, Braden R. "Achieving Sustainable Development through Industrial Ecology." *International Environmental Affairs* 4(1): 56-68.

Patel, C. Kumar N. "Industrial Ecology." *Proceedings, National Academy of Sciences, USA* 89 (February 1992): pp. 798-799.

Handout: Ecology and Industrial Ecology: Definitions

References: Hagen, J.B. *An Entangled Bank: The Origins of Ecosystem Ecology*, Rutgers University Press: New Brunswick, New Jersey, 1992.
Foundations of Ecology: Classic Papers with Commentaries, Leslie A. Real and James H. Brown, eds. 1991.
Ricklefs, R.E. *Ecology*, W.H. Freeman: New York, 1990.
Odum, E.P. *Fundamentals of Ecology* W.B. Saunders: Philadelphia, 1971
Odum, E.P. *Ecology and Our Endangered Life-Support Systems* Sinauer Associates, Inc. Sunderland, Mass., 1993.

Jan. 25 Industrial Metabolism
Material Balances
Nutrient Cycling
Anthropogenic vs Natural Fluxes
Cases: Mercury, Lead, Platinum

Reading: Ayres, Robert U. "Industrial Metabolism: Theory and Policy" in *The Greening of Industrial Ecosystems* National Academy Press: Washington, D.C. (1994): 23-37.

Frosch, Robert A., and Nicholas E. Gallopoulos. "Strategies for Manufacturing." *Scientific American* , no. September (1989): 144-152.

Reference: Odum, Eugene P. Chapter 5 in *Ecology and Our Life-Support Systems* Sinauer Associates, Inc.: Sunderland, Massachusetts.1993.

Jan. 30 Industrial Ecology of Chlorine
Current Uses of Chlorine in the Economy
IJC Policy and Industry Response
Dry cleaning vs. wet cleaning
Case: Future Uses of Chlorine

Reading: Hileman, Bette, Janice R. Long, Elisabeth M. Kirschner. "Chlorine Industry Running Flat Out Despite Persistent Health Fears." *Chemical and Engineering News* November 21, 1994: 12-26.

Feb. 1 Energy Flows in Ecosystems
Energy Balances
Trophic Levels and Efficiency
Case: Photosynthesis vs. Photovoltaics

Reading: Odum, Eugene P. Chapter 4 in *Ecology and Our Life-Support Systems* Sinauer Associates, Inc.: Sunderland, Massachusetts.1993.

Feb. 6 Industrial Ecology as a Metaphor
Food Webs/Industrial Ecoparks - An Analogy
Case: Kaloundborg

Other Related Frameworks
Pollution Prevention
Ecological Engineering

Readings: Tibbs, Hardin B. C. "Industrial Ecology: An Environmental Agenda for Industry." *Whole Earth Review* #77 (December 1992): 4-19.

Reference: Pollution Prevention Concepts and Principles (1994) Draft, National Pollution Prevention Center.

Freeman, Harry, Teresa Harten, Johnny Springer, Paul Randall, Mary Ann Curran, and Kenneth Stone. "Industrial Pollution Prevention: A Critical Review." *Air and Waste Management Association* 42, no. 5 (1992): 618-56.

III. Industrial Ecology: Tools and Applications

Feb. 8 Life Cycle Assessment (LCA): Components and Applications
Goal Definition and Scoping
Life Cycle Inventory Analysis
Life Cycle Impact Assessment
Life Cycle Improvement Assessment
Functional unit of analysis
Case: Beverage Containers

Reading: Curran, Mary Ann. "Broad-Based Environmental Life Cycle Assessment." *Environmental Science and Technology* 27, no. 3 (1993): 430-436.

Hunt, Robert G., Jere D. Sellers, and William E. Franklin "Resource and Environmental Profile Analysis: A Life Cycle Environmental Assessment for Products and Procedures." *Environmental Impact Assessment Review* Spring (1992):

Guinée, J. B., H.A. Udo de Haes, and G. Huppes, "Quantitative life cycle assessment of products. 1: Goal definition and inventory," *J. Cleaner Production* 1, no. 1 (1993): 1-13.

References: *Life Cycle Assessment: Inventory Guidelines and Principles (EPA 600/R-92/245)*. Cincinnati, OH: U.S. EPA, Office of Research and Development, Risk Reduction Engineering Laboratory, February 1993.

Life Cycle Design Guidance Manual: Environmental Requirements and the Product System. (EPA/600/R-92/226). Cincinnati, OH: U.S. EPA, Office of Research and Development, Risk Reduction Engineering Laboratory, January 1993.

Feb 13 Life Cycle Inventory Analysis
System Boundaries
Process Flow Diagram
Input/Output Analysis
Case: Diapers - Disposable vs Reusable?

Reading:	Vizcarra, A.T., Lo K.V. and P.H. Lio "A Life-Cycle Inventory of Baby Diapers Subject to Canadian Conditions." *Environmental Toxicology and Chemistry,* Vol. 13 No. 10 (1994): 1707-1716.
Feb 15	Life Cycle Inventory Analysis Allocation Rules Data Sources Data Quality Case: Cups - Paper, Plastic or Ceramic?
Readings:	Hocking, Martin B. "Paper Versus Polystyrene: A Complex Choice." *Science* 251 (1991): 504-505. Wells, Henry A., Neil McCubbin, Red Cavaney, Bonnie Camo, and M. B. Hocking. "(Letters) Paper versus polystyrene: Environmental impact." *Science* 252, no. 7 June (1991): 1361-1363. Hocking, Martin B. "Disposable Cups Have Eco Merit" *Nature* 369, 12 May (1994): 107.
Feb. 18 -26	Spring Break
Feb. 27	Life Cycle Inventory Analysis Energy: Precombustion, Process, Embodied Transportation Energy Transportation Emissions Case: Material Selection for the Automobile - Aluminum, Steel or Plastic?
Reading:	Young, Steven B. and Willem H. Vanderburg "Applying Environmental Life-Cycle Analysis to Materials" *Journal of Materials* April (1994): 22-27.
Handout:	Transportation Data - Appendix A Franklin Associates
Mar. 1	Life Cycle Inventory Analysis Stages of the Life Cycle - Special Issues
Reading:	Portney, Paul R. "The Price Is Right: Making Use of Life Cycle Analyses." *Issues in Science and Technology* Winter (193-194): 69-75.
Mar. 1 - 8	Mid-term Exam Period (3 day take home)
Mar. 6	Life Cycle Impact Assessment Classification Characterization Valuation Critical Volume Approach Case: EPS

Reading: Guinée, J. B., Reinout Heijungs, H.A. Udo de Haes, and G. Huppes, "Quantitative life cycle assessment of products 2. Classification, valuation, and improvement analysis," *J. Cleaner Production* 1, no. 2 (1993): 81-91.

Reference: Naugle, Dennis F. and Terrence K. Pierson "A Framework for Risk Characterization of Environmental Pollutants" *J. Air and Waste Management Association* Vol. 41, No. 10 (1991): 1298-1307.

Mar. 8 Life Cycle Assessment

Case: Milk Packaging

Mar. 13 Life Cycle Design
- Life Cycle Framework
- Life Cycle Management
  - Multi-stakeholders
  - Internal Elements: Environmental Management System
  - External Factors
- Life Cycle Design Process
  - Needs Analysis
  - Specification of Requirements
  - Selection and Synthesis of Design Strategies
  - Design Evaluation

Reading: Keoleian, Gregory A., and Dan Menerey. "Sustainable Development by Design: Review of Life Cycle Design and Related Approaches." *Journal of the Air and Waste Management Association* (1994) 44: 644-668.

Mar. 15 Design Requirements
- Checklists and Matrices
- Multi-objective analysis

Case: AlliedSignal Oil Filters

Reading: Chapter 4 Life Cycle Design Guidance Manual

Mar. 20 Design Strategies
- Product Life Extension
- Material Oriented Strategies
  - Material Recycling
  - Material Selection
  - Material Intensiveness
- Process Oriented Strategies
- Distribution Oriented Strategies

Class Exercise: Lease vs Sell - Business Phone

Reading: Chapter 5 in *Life Cycle Design Guidance Manual: Environmental Requirements and the Product System. (EPA/600/R-92/226).* Cincinnati, OH: U.S. EPA, Office of Research and Development, Risk Reduction Engineering Laboratory, January 1993.

Stahel, Walter R. "The Utilization-Focused Service Economy: Resource Efficiency and Product-Life Extension" in *The Greening of Industrial Ecosystems* National Academy Press: Washington, D.C. (1994): 178-190.

Herman, R., S.A. Ardekani, J.H. Ausubel, "Dematerialization," *Technology and Environment* , National Academy Press: Washington, (1989): pp. 50-69.

Mar. 22 Design Evaluation (LCA Tools and Environmental Metrics)
- Allenby Matrix
- EPS
- Sony Resource Productivity Measure

Reading: Allenby, Braden R. "Design for environment: A tool whose time has come." *SSA Journal* , no. September (1991): 6-9.

Apr. 3 Life Cycle Costing/Full Cost Accounting
Case: Light Bulbs

Reading: Chapter 7 Life Cycle Design Guidance Manual
Lund, Robert T. "Life-Cycle Costing: A Business and Societal Instrument." *Management Review* 67, no. 4 (1978): 17-23.

Apr. 5 Life Cycle Framework for Environmental Marketing and Labelling
- FTC Guidelines
- Report Cards
- Seals of Approval

Case: Green Seal, Blue Angel, Green Cross

Apr. 10 Term project presentations

Apr. 12 Term project presentations

Apr. 17 Policy and Regulations for Promoting Industrial Ecology
- U.S. EPA Common Sense Initiative

Reference:
Apr. 17 Term Project Papers Due

Apr. 24 Final Exam

Course Evaluation

Class Participation	10%
Assignments	15%
Mid-Term Exam	25%
Final Exam	25%
Term Project	25%

Exams

Midterm	Take home exam. 3 days to complete. Sign out exam from Kathy Hall during normal business hours sometime between March 1 and March 8. For example, if you pick up the exam at 9 am on Wednesday March 1 it will be due back before 9 am on March 4. Late exams will be marked down.
Final	In-class exam. two hours.

Term Projects

A term project will be assigned on Jan. 18 and project groups will be formed to facilitate interdisciplinary collaboration. Your group will choose a product and apply industrial ecology principles and tools to assess the environmental impacts associated with the product and identify opportunities for its improvement. The term project includes a group paper and presentation.

Pollution Prevention and Industrial Ecology
NATIONAL POLLUTION PREVENTION CENTER FOR HIGHER EDUCATION

Introduction to Energy and Environmental Problems

R. H. Socolow
PA 525/MAE 559, Spring 1994
Princeton University

Public Affairs 525 / Mechanical and Aerospace Engineering 559

INTRODUCTION TO ENERGY AND ENVIRONMENTAL PROBLEMS

Instructor: R. H. Socolow, Director
Center for Energy and Environmental Studies
H-104 Engineering Quadrangle
Phone: 8-5446

MONDAYS, 1:00-4:10 p.m. in Room 12, Woodrow Wilson School

COURSE OUTLINE FOR 1994

R. H. Socolow

Week 1: Introduction

Week 2: The Global Environment

Week 3: Sources of Human Impact: Population, Industrialization, Technology, Values

Week 4: Industrial Ecology: Materials Flows, Vulnerabilities, and Reconfigurations

Week 5: Energy Use, Efficiency, Lifestyle

Week 6: Land Management and Solar Energy

Week 7: Reserves and Resources of Fossil Fuels

Week 8: Air Quality and Fossil Fuels

Week 9: Nuclear Energy Options

Week 10: Nuclear Problems: Accidents, Waste Disposal, Proliferation

Week 11: Biodiversity

Week 12: Stewardship

PA525/MAE559 Spring 1994

STUDENT TERM PAPERS

Artur Chabowski, "A Comparative Assessment of Pollution Regulations in Poland and in the United States."

Kyle Danish, "The Takings Debate and Possible Implications for the Expanding Role of Government in Environmental Management"

Tom Davis, "Overcoming the Brownfield Barrier: Synthesizing Environmental Cleanup and Economic Development"

Robert Heeter, "Rethinking Fusion via Industrial Ecology"

Wendy Hughes, "Intergenerational Equity"

Olga Kim, "Building Cities in the Desert"

Verna Lomax, "The Potential Benefits of Commuting by Bicycle in the Washington, DC Area"

Avinash Ratta, "The Challenge of Nuclear Disarmament in South Asia"

Glenn Reichart, "Recovery of Sulfur from Coal Combustion Gases: A Study Balancing Environmental Concern with Economic Opportunity"

Ted Stephens, "History of the Endangered Species Act and the Reauthorization Battle"

Hitoshi Tagawa, "Alternative Options for the Expansion of the Supply of Natural Gas to Japan"

Darcy Zarubiak, "The Facts and Politics of the Duck Island Incinerator"

Public Affairs 525/Mechanical and Aerospace Engineering 559

READINGS - Spring Term 1994

Week Two:

William Cline, Global Warming: The Economic Stakes. Institute for International Economics, 1992.

Albert Gore, Earth in the Balance: Ecology and the Human Spirit. Boston: Houghton Mifflin, 1992.

Syukuro Manabe and Ronald Stouffer, "Century-scale effects of increased atmospheric CO2 on the ocean-atmosphere system." Nature, Vol. 364, July 15, 1993, pp. 215-218.

Robert Socolow, Graphs of geophysical data about the atmosphere. (Handout).

Week Three:

"Earth Summit: Convention on Climate Change" United Nations Conference on Environment and Development, Rio de Janeiro, Brazil, 6/3-14/92 with attachment: Memo from William K. Reilly to Clayton Yeutter re Biodiversity Convention.

"World Development Report 1992: Development and the Environment" pages 313 thru 356.

"The Climate Change Action Plan" by W. J. Clinton and A. Gore - thru page 31.

"Emissions of Greenhouse Gases in the United States 1985-1990" thru page 23.

Draft Chapter for Industrial Ecology and Global Change, R. H. Socolow, C. J. Andrews, F. G. Berkhout, and V. M. Thomas, eds., Cambridge University Press, 1994 - "Human Impacts on the Carbon and Nitrogen Cycles" by R. Ayres, W. Schlesinger, and R. Socolow.

Also:

From "Economics of the Environment" (3rd edition) edited by Robert Dorfman and Nancy S. Dorfman, Norton 1993.

Chapter 26 Scott Barrett, "International Cooperation for Environmental Protection"

Chapter 27 Thomas C. Schelling, "Some Economics of Global Warming"

Chapter 28 Yoshiki Ogawa, "Economic Activity and the Greenhouse Effect"

From Richard Benedick, "Ozone Diplomacy" Harvard University Press 1991.

Week Four:

"Towards an Industrial Ecology," by R. A. Frosch and N. E. Gallopoulos.

Table of Contents: Industrial Ecology and Global Change

Chapters: "Six Perspectives from Industrial Ecology" by Robert Socolow
"Metals Loading of the Environment: Cadmium in the Rhine Basin" by William Stigliani, Peter Jaffe, and Stefan Anderberg
"Emissions and Exposure to Metals: Cadmium and Lead" by Valerie Thomas and Thomas Spiro

"Product Life-Cycle Management to Replace Waste Management" by Michael Braungart

"Free-Lunch Economics for Industrial Ecologists" by Theodore Panayotou and Clifford Zinnes

INDUSTRIAL ECOLOGY - Third Draft. By T. E. Graedel and B. R. Allenby.

Week Five:

"The Coming Age of Conservation," Robert H. Socolow, Ann. Rev. Energy, 1977.

"Energy for Planet Earth," Ged R. Davis, Scientific American, Vol. 263, No. 3, Sept. 1990.

"Efficient Use of Electricity," A. Fickett et al., Scientific American, Sept. 1990.

"Market Transformation Strategies to Promote End-Use Efficiency," Howard Geller and Steven Nadel, Review Draft, 2/94.

Press Relese, The White House, Office of the Press Secretary, 9/29/93.

"Pipe Dream," Gary Stix, Scientific American, February 1994.

"Fuel Cells, Their Fuels, and the U.S. Automobile," R. H. Williams, Paper prepared for the First Annual World Car 2001 Conference, U. of Cal. at Riverdale, June 1993.

Week Six:

"Energy from the Sun" by Carl J. Weinberg and Robert H. Williams, Scientific American, Vol. 263, No. 3, 1990.

"Roles for Biomass Energy in Sustainable Development," Robert H. Williams.

"Toward Ecological Guidelines for Large-Scale Biomass Energy Development," Report of a Workshop for Engineers, Ecologists, and Policy Makers convened by National Audubon Society, May 1991.

"Wind Energy: Technology and Economics," by Alfred J. Cavallo et al., Renewable Energy: Sources for Fuels and Electricity, Island Press, 1993.

"Energy Strategy: The Road Not Taken?" by Amory B. Lovins, Soft Energy Paths: Toward a Durable Peace, Harper Colophon Books.

Week Seven:

BP Statistical Review of World Energy, June 1992.

The Petroleum Handbook, Sixth Edition, Elsevier, 1983.

H. W. Menard, Geology, Resources and Society: An Introduction to Earth Science, W. H. Freeman and Co.

Week Eight:

Thomas E. Graedel and Paul Crutzen, "The Changing Atmosphere," Scientific American, September 1989, pp. 58-68.

Robert Stavins and Bradley W. Whitehead, "Pollution Charges for Environmental Protection: A Policy Link Between Energy and the Environment," Ann. Rev. of Energy and Envir., Vol. 17, pp. 187-210.

Marc H. Ross and Robert H. Socolow, "Fulfilling the Promise of Environmental Technology," Issues in Science and Technology, VII, 3, Spring 1991, pp. 61-66.

Paul Slovic, "Perception of Risk," Science, 236, April 1987, pp. 280-285.

Marc Ross, "Why Cars Aren't as Clean as We Think," Technology Review, February/March 1994.

J. G. Calvert, J. B. Heywood, R. F. Sawyer, J. H. Seinfeld, "Achieving Acceptable Air Quality" Some Reflections on Controlling Vehicle Emissions," Science, Vol. 261, July 2, 1993, pp. 37-45.

Week Nine:

Art Hobson, "Physics: Concepts and Connections," pages 325-373.

William Sweet, "How Reactors Work," Chapter 1, Nuclear Age: Atomic Energy, Proliferation, and the Arms Race, Congressional Quarterly, Inc., pages 29-45.

U. Colombo and U. Farinelli, "Progress in Fusion Energy," Ann. Rev. of Energy and Envir., Vol. 17, pages 123-159.

Week 10:

John Holdren, "Radioactive-Waste Management in the United States: Evolving Policy Prospects and Dilemmas," Annual Review of Energy and Environment, Vol. 17, pages 235-239.

Kai Erikson, "Out of Sight, Out of Our Minds," The New York Times Magazine, March 6, 1994.

Frans Berkhout and Harold Feiveson, "Securing Nuclear Materials in a Changing World," Annual Review of Energy and Environment, Vol. 18, pages 631-665.

Executive Summary, Management and Disposition of Excess Weapons Plutonium, Committee on International Security and Arms Control, National Academy of Sciences, National Academy Press, 1994.

Week Eleven:

Aldo Leopold, "A Sand County Almanac and Sketches Here and There," Oxford University Press, pp. 201-226.

George Sessions and Bill Devall, Deep Ecology, Gibbs Smith, 1985, Chapter 5.

Edward O. Wilson, "Threats to Biodiversity," Scientific American, September 1989, pp. 108-116.

Walter E. Westman, "Managing the Biodiversity," Bioscience, Vol. 40, No. 1, pp. 26-33.

Robert Repetto, "Deforestation in the Tropics," Scientific American, April 1990, Vol. 262, No. 4, pp. 36-42.

Marguerite Holloway, "Nurturing Nature," Scientific American, April 1994, pp. 98-108.