

AC 2008-2767: ENERGY AND ENVIRONMENTAL ECONOMICS CORE COURSE SEQUENCE FOR AN INTERDISCIPLINARY ENGINEERING SCIENCE DOCTORAL PROGRAM

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Energy and Environmental Economics Core Course Sequence for an Interdisciplinary Engineering Science Doctoral Program

Abstract

An innovative feature of the Energy & Environmental Ph.D. Program at North Carolina Agricultural & Technical State University is a two course sequence in energy and environmental economics. The objective of these core courses is to provide engineering science doctoral students with economics tools that they can use in their dissertations and throughout their careers in analyzing new energy and environmental technologies. The first course, *Theory and Practice of Energy and Environmental Economic Policy Analysis*, provides the economic framework necessary for analyzing energy and environmental issues. Microeconomic and macroeconomic principles and analytical techniques relevant to the analysis of energy markets and environmental protection are covered. Current energy and environmental regulatory systems at the state, national, and international levels are presented. The second course, *Application of Energy and Environmental Economic Policy Analysis*, provides the quantitative economic techniques necessary for analyzing energy and environmental projects and issues. The course covers engineering economics techniques for energy project valuation and econometric techniques used in forecasting the supply of and the demand for energy and environmental services. Presented herein are details of the content and methods utilized in the courses and student feedback on them.

Introduction

The Energy & Environmental (EES) Ph.D. program is a new interdisciplinary graduate program at North Carolina Agricultural & Technical State University that is now in its third year of operation.¹ It has a current student body of eighteen students with its first graduate having graduated during fall 2007. The disciplinary backgrounds of the students include chemical engineering, mechanical engineering, civil and environmental engineering, electrical engineering, environmental science, applied mathematics, chemistry, physics, biology, and agricultural economics. A feature of the program that was incorporated into its initial design is a thread of exposure to energy and environmental economics. The rationale for inclusion of this thread included (1) to provide a vehicle for interdisciplinary conversations among students with a variety of engineering and physical science backgrounds, (2) to respond to numerous reports of the need for engineering graduates with strong technical skills as well as a broader education, and (3) to emphasize to students that energy and environmental technology decisions are driven by economic considerations.

The two course sequence EES 810 (*Theory and Practice of Energy and Environmental Economic Policy Analysis*) and EES 811 (*Application of Energy and Environmental Economic Policy Analysis*) are the starting point for the thread of economic analysis that runs throughout the EES course of study. This part of the EES curriculum is designed to provide students with some basic economic analysis tools that can be used throughout their career to analyze energy and environmental technologies not just in terms of technology issues but also in terms of economic and regulatory issues. EES 810 and EES 811 are required core courses that are taken during the first two semesters in the EES program. Material from the courses is included in the written qualifying exam that students take at the end of their first year of study. Additional

program components that build upon this exposure to energy and environmental economics are seminars on energy and environmental economic topics and inclusion in the dissertation of some economic analysis of the technology that has been researched.

During the three years in which the courses have been taught, two different instructors have been utilized. The instructor for the first offering of the courses was a part-time adjunct faculty member who had recently retired after more than thirty years working with the Research Triangle Institute (RTI), his last position being Director of RTI's Public Utility Economics program. His educational background was a B.S. in Nuclear Engineering and a Ph.D. in Economics with a minor in Nuclear Engineering. He coauthored the book *Electric Utility Load Management*, served on the Board of Directors of North Carolina Green Power, and had previous microeconomics and macroeconomics teaching experience. This instructor had many personal experiences working on energy and environmental economics projects that he was able to share with the students.

As the benefit of these courses to the EES students was demonstrated, the decision was made to hire a full time instructor to teach these courses. The faculty member hired has a B.S. and M.S. in Applied Mathematics and a Ph.D. in Agricultural Economics. Her research experience is in production economics, econometrics, design of carbon sequestration policies, and economic and environmental trade-offs of expanded ethanol production. She had previously taught an undergraduate Economics of Energy Resources and Policy course.

Challenge of Teaching to Students with Diverse Backgrounds

A big challenge in teaching the courses as doctoral level courses is that the economics backgrounds of the students are highly variable and some students have had little previous exposure to economics. Another source of diversity in the courses is the presence of international students from a number of different countries. To aid with overcoming these challenges, a concise economics primer has been developed that students are required to go through and answer questions about before the first meeting of EES 810. Since some students have had some economics coursework previously while others have not, the primer is intended to help "level the playing field" in terms of economics background among these students. To this point the accountability for going through the primer has only been in terms of the questions in it being the first homework assignment in the course. In the future, we plan to provide a course pre-test to provide a quantitative indication of the success of the primer approach and to direct future revisions of it.

The primer focuses primarily on microeconomics. It also presents some key concepts in macroeconomics, environmental economics, and engineering economics that are useful in the energy area. The outline of the primer is as follows:

Microeconomics

- Economics – Resource Allocation Guidance and Distribution Effects (Allocation and Equity). Economics exists because resources are scarce (limited) relative to unlimited wants, and thus the concept of opportunity costs. Positive vs. Normative Economics.
- Demand
 - *Movements along the curve

- *Movements of the curve – demand shifters
- Supply
 - *Movements along the curve
 - *Movements of the curve – supply shifters
- Elasticities (dimensionless) -- $(\% \text{ change in response}) / (\% \text{ change in stimulus})$
 - *Price elasticity of demand
 - *Income elasticity of demand
 - *Elasticity of substitution in demand
 - *Price elasticity of supply
 - *Elasticity of substitution in supply – products or services, inputs
- Relationships among elasticities – especially useful one is price elasticity of demand facing a supplier (firm) in a marketplace or a country in international trade
- Shortages, surpluses, price floors, price ceilings, price discrimination
- Consumer surplus, producer surplus, deadweight loss
- Utility and demand – short run, long run
- Production and supply – short run, long run
- Market organization and effects on prices and quantities in product and input markets

Macroeconomics (much less emphasis than Microeconomics)

- Consumption, saving and investment – the IS curve and fiscal policy (who, tools)
- Demand for and supply of money – the LM curve and monetary policy (who, tools)
- International trade, investment, balance of payments, and exchange rates (fixed, floating) – the BP curve and external policy (who, tools)
- The basic macro identity

Application of Microeconomics to Energy Economics

- Micro tools – demand and supply of energy by type
- Consumption characteristics, conservation, and substitution among types
- Production characteristics – especially conventional vs. alternative
- Taxes and subsidies, price caps and floors
- Regulation, especially electricity – types and rationale, history, effects

Environmental Economics Concepts Useful in Energy Economics

- Three ways environment contributes to economy – services are direct input into production, repository for residuals from production, direct input into consumption
- Market failures vs. market barriers
- Externalities, positive and negative
- Public goods
- Coase Theorem
- Overcoming market failures – taxes, subsidies, command and control, market based (trading of rights)
- Project evaluation and social rate of discount

Engineering Economics Concepts Useful in Energy Economics

- Time value of money and discounting

- Present value and future value
- Levelized costs and benefits
- Use in project evaluation

The primer has been useful in helping students to come up to speed with economics jargon before the start of EES 810. The primer is also geared to help wet students interest in the topics to be covered in the course. The macroeconomics section of the primer that summarizes U.S. federal government *fiscal policy* and *monetary policy* is of particular interest to international students who have had little or no previous exposure to this information and have lived under different systems of government.

Following is an excerpt from the environmental economics section of the primer that demonstrates how students are introduced in the primer to some key concepts and terminology:

There are three ways the environment contributes to an economy. First, the environment provides environmental services directly for consumption – e.g., breathing clean air; drinking clean water; visiting local, state, and national parks, etc. Second, the environment provides environmental inputs directly into production processes – e.g., air, water, and land for energy production, transportation, and conversion. Third, the environment serves as a repository for residuals (e.g., pollutants) from economic activity, especially production activities.

These environmental services are typically not priced in private markets, including energy markets. As a result, they do not contribute to a producer's costs (or the costs of other users), so producers and other users tend to use more of these services than they would if they were priced. The term *negative externality* refers to this overuse, and environmental services that are overused are referred to as *environmental externalities*. The costs to society associated with this overuse are referred to as *environmental external costs*. By contrast, some types of services (e.g., vaccinations) are underused because persons who use them cannot capture the benefit they convey (e.g., a lower level of communicable disease) to persons who don't use them. The non-users are often called "free riders", and the term *positive externality* refers to this underuse.

Positive and negative externalities are a form of *market failure*. A market failure exists when markets aren't able to price goods or services. Another example of a market failure is a *public good*. A public good (e.g., national defense) is a good or service where one person's consumption or use doesn't diminish that of others and where it is very difficult to exclude anyone from consuming or using it. Public goods are prone to overconsumption and overuse. The term *market barrier* is not the same as the term market failure. Market barriers are more common than market failures and are simply hurdles that must be overcome to enter or otherwise participate in markets. Examples of market barriers include inadequate information, high initial costs of purchasing a piece of equipment, financing constraints, etc.

There are several ways to deal with market failures such as externalities in energy production. The most relevant ways can be divided into two types of approaches. One is the *command-and-control* approach, and the other is the *market-based* approach. In the command-and-control approach, economics aren't a consideration. Typically, the regulatory

authority (such as the U.S. Environmental Protection Agency) simply mandates a pollution limit (e.g., tons of emissions of a given type per designated time period) and mandates a technology for companies to use to get there (e.g., best available control technology or BACT). This type of approach is often called an “end of pipe” approach because it treats pollution after it is generated. Another type of command-and-control approach is to mandate process controls or limits on the use of polluting inputs. This type of approach is often called a “process control” approach because by affecting the use of inputs and the production process, it helps to prevent pollution from being generated.

The market-based approach provides a polluter with greater flexibility allowing it to determine and employ the least-cost way for it to meet a pollution reduction (or limit) target. The polluter may then choose whether to install pollution treatment equipment, change the production process, and/or substitute less-polluting inputs for more polluting ones. This approach recognizes that a “one size fits all” approach may not be economically efficient, and the least-cost solution for one polluter may then differ from that of other polluters. One type of market-based approach is the use of taxes and subsidies. In cases where taxes are levied on polluters, the tax rate may be related to the environmental externality costs per unit of pollutant. Such taxes are one way of “internalizing the externality” because the producer now sees a tax where there was no cost before. In the cases where subsidies are provided, they typically are provided for the use of “clean” inputs (e.g., clean coal) or the production of “clean” products (e.g., non-polluting alternative energy sources). Subsidies are essentially the flip side of taxes, encouraging the use of environmentally friendly inputs and the production of environmentally-friendly products (and research and development into both inputs and products), whereas taxes discourage the use of environmentally unfriendly inputs and the production of environmentally unfriendly products.

Another type of market-based approach is based on the *Coase Theorem*. This theorem states that the allocation of property (ownership) rights for a resource do not affect the allocation of that resource between competing uses if trading of these rights can occur, if good information is widespread and essentially costless, and if transaction costs are very small. If these assumptions hold, not only will the allocation of property rights not affect the allocation of the resource among competing uses, but the resource will also be deployed in its highest and best use. This theorem was originally formulated to cover the situation of land disputes between farmers and cattlemen. It now is relied on for the development of trading systems (e.g., cap-and-trade systems) for pollution permits (e.g., rights to emit SO_x, carbon, etc).

The engineering economics section of the primer emphasizes that this area of economics deals mostly with tools for project evaluation and is focused on costs and benefits associated with equipment behavior, not the behavior of individuals, businesses, and organizations. Because of the long-lived nature of equipment and engineering projects, benefits (e.g., project revenues) and costs will be spread over several future time periods. As a result, a key concept in engineering economics is the time value of money.

EES 810: Theory and Practice of Energy and Environmental Economic Policy Analysis

The course content between EES 810 and 811 has been designed to allow students entering the EES program in the spring to be able to start with 811 instead of having to wait to take 810. This

is accomplished by having EES 810 concentrate on economic and policy principles and methods while EES 811 concentrates on econometrics and regression analysis. The current syllabus for EES 810 is as follows:

Course description:

The objective of the course is to provide a better understanding of economic and policy issues of relevance to energy and environment. The course applies basic economic principles and methods to examine key aspects of allocation of natural resources, energy sources and markets, as well as regulation and energy and environmental policy issues.

Text:

Required: TT: Tietenberg, T., *Environmental and Natural Resource Economics*, 7th Edition, Pearson Addison Wesley, 2006

Course outline:

<u>Topic</u>	<u>Lecture</u>	<u>Text chapters</u>
I. Introduction	Aug. 22, 24	Ch. 1
II. Basic tools and concepts		
A. The economic perspective	Aug. 27, 29, 31	Ch. 2
B. Sustainable development	Sep. 5, 7, 10	Ch. 5
EXAM 1	Sep. 12	Ch. 1, 2, 5
C. Cost/benefit analysis	Sep. 14, 17, 19	Ch. 3
D. Property rights, externalities,	Sep. 21, 24, 26	Ch. 4
III. Natural resources		
A. Introduction	Sep. 28, Oct. 1, 3	Ch. 7
EXAM 2	Oct. 5	Ch. 3, 4, 7
B. Depletable resources		
1. Energy	Oct. 10, 12, 15, 17, 19	Ch. 8
2. Recyclable	Oct. 22, 24	Ch. 9
IV. Environmental economics		
A. Pollution control mechanisms	Oct. 26, 29, 31, Nov. 2	Ch. 15
EXAM 3	Nov. 5	Ch. 8, 9, 15
B. Air pollution		
1. Stationary source	Nov. 7, 9, 12	Ch. 16
2. Regional and global	Nov. 14, 16, 19	Ch. 17
C. Water pollution	Nov. 26, 28, 30, Dec. 3	Ch. 19
FINAL EXAM	To be announced	Comprehensive

An example of typical homework assignment is as follows:

To meet local environmental standards, a firm is required to achieve a specific emission reduction, $x = 9$ tons/year. The firm has 3 factories, and because of the differences in the ages of the factories, the costs of emission reduction are different. The marginal costs are given as

$$\begin{aligned} MC_1 &= x_1, \\ MC_2 &= 3 x_2, \end{aligned}$$

$$MC_3 = 4 + 2 x_3.$$

Here MC_i is the marginal cost of reducing emissions at the i -th factory in \$ per ton per year, and x_i is the magnitude of the emissions reduction at the i -th factory in tons per year, $i=1,2,3$.

- i) Find the cost-minimizing allocation of the reduction in emissions among the 3 factories analytically and illustrate your solution graphically.
- ii) What is the minimum cost of achieving the required emission reduction? What is the marginal cost of achieving the required emission reduction?
- iii) Repeat questions i)-ii) for the cases when $x = 14.5$ and $x = 4$. Briefly comment on the differences in your findings under the alternative values of x .
- iv) Now suppose that the environmental standards have not been set yet. Rather, they are being actively discussed by the local government. To show its good will (or may be for the public relations purposes), the firm decides to be proactive and cut emissions before the new standards are introduced. The firm still wants to do so in a cost-effective way and sets aside \$40 for these purposes. What is the maximum amount of emission reduction that the firm can achieve? In answering this question, begin by stating what analytical problem you are solving; you may want to program your calculations in Excel to answer the question.

Economics and global warming is an area that lends itself to incorporating a number of important economic principles into interesting discussions during the course. Here is an outline of a few of these opportunities:

Analytical Complexities

- (a) Global warming is a transboundary environmental issue *par excellence*. Key complexities include:
 - (1) uncertainties in emission rates of greenhouse gases (GHG) and their atmospheric lifetimes and concentrations
 - (2) uncertain effects of such concentrations on temperature, precipitation, and climate at different geographical levels
 - (3) uncertain effects of global climate change (GCC) on a wide range of variables of economic interest including agriculture, sea levels, human health, biodiversity, and basic ecological and environmental systems
- (b) There are major relevant differences among countries with respect to:
 - (1) past, present, and prospective GHG emissions
 - (2) vulnerability to GCC
 - (3) costs of GHG emissions control
 - (4) income levels, and hence discount rates (DR); valuation of damages; and willingness and ability to pay (WTP and WAP) for controls
 - (5) ethical, philosophical, and religious beliefs
 - (6) institutional capacity to formulate, implement, and enforce controls
- (c) Countries are linked via international trade and flows of financial capital, so attempts to control global warming (GW) will affect income, competitive positions, and international trade patterns

Taxes and Quotas

- (a) how to account for existing differences among countries in energy taxes
- (b) how to treat trade in fuels and energy-intensive products, which is important if taxes are not universal in coverage (i.e., across all countries)
- (c) where the appropriate point is in the extraction-processing-consumption chain (and maybe even the transportation links in between each step) to apply the tax
- (d) whether credit is given in the redistributive scheme to reforestation activities
- (e) how to prevent erosion of the tax through government subsidies to energy-intensive industries
- (f) how to establish a tax that is sufficiently permanent to affect major investment decisions yet flexible enough to be adjusted for new information
- (g) how to monitor the use of energy and the collection of the tax

EES 811: Application of Energy and Environmental Economic Policy Analysis

During the first offering of EES 811, the amount of material covered was overly ambitious and included Energy Utility Planning and Operation, Energy Environmental Issues, Economic Regulation of Energy Utilities, Environmental Regulation of Energy Utilities, Evaluating Green Power and Demand Side Markets, and Intellectual Property and Patents.²⁻⁷ It was also attempted to provide the students with some background on entrepreneurship. Currently, we have gone away from incorporating this material in the EES 810-811 sequence and instead will be providing the opportunity for exposure to this material through elective courses, a one credit hour Introduction to Research Ethics Course that has been added to the curriculum, and seminars. The current syllabus for EES 811 is as follows:

Course description:

The objective of the course is to introduce econometrics as a field of economics and provide hands on experience with application of econometrics approaches to economic problems of relevance to energy and environment.

Text:

Required: Studenmund, A. H., *Using Econometrics: A Practical Guide*, 5th Edition, Pearson Addison Wesley, 2006

Course outline:

<u>Topic</u>	<u>Lecture</u>	<u>Text chapters</u>
I. Statistical principles	Jan. 7, 9, 11	Ch. 16
II. Basic regression model		
A. Overview of regression analysis	Jan. 14, 16, 18	Ch. 1
B. Ordinary least squares	Jan. 23, 25, 28, 30	Ch. 2
C. Using regression analysis	Feb. 1, 4	Ch. 3
EXAM 1	Feb. 6	Ch. 16, 1, 2, 3
D. The classical model	Feb. 8, 11, 13, 15	Ch. 4
E. Hypothesis testing	Feb. 18, 20, 22, 25	Ch. 5
III. Violations of the classical assumptions		
A. Specification search	Feb. 27, 29	Ch. 6
A. Specification search (cont.)	Mar. 10, 12	Ch. 6

EXAM 2	Mar. 14	Ch. 4, 5, 6
B. Choosing a functional form	Mar. 17, 19	Ch. 7
C. Multicollinearity	Mar. 24, 26, 28, 31	Ch. 8
D. Heteroscedasticity	Apr. 2, 4, 6, 9	Ch. 10
EXAM 3	Apr. 11	Ch. 8, 9, 15
IV. Extensions of the basic regression model		
A. Dummy dependent variable	Apr. 14 – Apr. 30	Ch. 13
FINAL EXAM	Week of May 1 – 7	Comprehensive

An examples of typical homework assignment is as follows:

Table G.1 (provided as an Excel file) gives data, reproduced from D.R. Cox and E.J. Snell, “Applied Statistics: Principles and Examples”, Chapman and Hall, New York, NY, 1981, p.82, on light water reactor (LWR) power plants constructed in the USA. Use regression analysis to investigate the determinants of the capital cost involved in the construction of LWR power plants. The notation used in Table G.1 is explained in Table G.2. The final six lines of data in Table G.1 relate to power plants for which there were partial turnkey guarantees and for which it is possible that some manufacturers’ subsidies might be hidden in the quoted capital costs. Consider the following linear regression model

$$\ln\left(\frac{C_i}{S_i}\right) = \beta_1 + \beta_2 N_i + \beta_3 NSQ_i + \beta_4 NE_i + \beta_5 PT_i + \varepsilon_i,$$

Here

- C Cost in dollars $\times 10^{-6}$, adjusted to 1976 base
- N Cumulative number of power plants constructed by each architect-engineer
- NSQ N squared
- NE Dummy variable, =1 if plant constructed in North-East region of USA, and zero otherwise
- PT Dummy variable, =1 if partial turnkey plant, and zero otherwise.

- 1) Hypothesize the expected signs of the coefficients.
- 2) Provide summary statistics (means and standard deviations) on all the data. Report the number of significant digits in accordance with the standard econometrics practices.
- 3) Use the data to fit the linear regression equation.
- 4) Interpret what all of the coefficients mean (be careful with the interpretation of marginal effects of N).
- 5) Show that your estimated model implies that the cost per unit of capacity is about 24% higher for the plants located in the NE.
- 6) Show that your findings imply that the cost per unit of capacity is about 37% lower for the turnkey plants.

SAS[®] software is used for part of EES 811 to provide students with a computational tool that they can use for simple economic analysis. Regression models may be used to estimate some common valuation models in environmental economics, such as Willingness-to-Pay (WTP), Contingent Valuation (CV), and Contingent Ranking (CR). In another application, regression

models can be used as the basis for forecasting and even partial validation of a forecast if there are enough data to split the time series in half so that the analyst can estimate the parameters of the model on the first half and then use the second half to see how valid the model is. Logistic regression models may be used to estimate "choice" models, like technology adoption and voluntary program participation models. These models can then be used to forecast market potential and possibly (given adequate time series data) the time rate of market penetration.

Student Evaluation

Student feedback on the EES 810-811 sequence has been solicited using the questions below. Given that the courses have been taught by two different instructors with significantly different experience, some of the answers obtained have been contradictory. Provided is a sampling of qualitative remarks in areas where there appears to be consensus.

Do you anticipate the material you covered in EES 810/811 to be useful during your career? If so, how will it be useful?

"The material covered is useful because it aids in a real world understanding of how environmental issues affect economies and how policy is made based on information passed on by environmental economists. It is particularly useful to me because I am interested in subsidies that governments need to pay to have private businesses adopt environmentally safe practices. This sequence therefore provides the background needed to conduct research and provides a good introduction to rigorous economic applications."

"I believe the economics material will be useful for cost estimates, budgets, and planning. I am not so sure that the energy efficiency course in the old curriculum will be used in my career."

Do you anticipate having taken the EES 810/811 sequence to be helpful in obtaining a job upon graduation? If so, how will it be helpful?

"Having taken the sequence will be helpful in obtaining a job upon graduation in that it prepared me for research that I am interested in conducting in this field."

"Yes, I think they will be helpful in obtaining a job upon graduation, because they helped me in better understanding of how to tackle economic issues of the environment."

"I think it may be helpful. Employers are interested in cost effectiveness, and having taken this course we were exposed numerous issues which we may be encountered in the workplace."

"Not really. I don't expect to be looking for that kind of a job."

Not having an extensive previous exposure to economics, what were the greatest challenges to doing well in the course?

"Learning the definitions and remembering the graphs associated with different concepts."

"The main challenge was in understanding the economic terminology and how to implement economic rules taken in decision making or suggestion of a policy for a firm/institute."

“Understanding the basics took some time. This was not easy considering the amount of information which was covered during one semester.”

“I would like to see some "dummies guide to the evolution of economics." A couple lectures or a side text that goes over the main characters and their importance.”

Which topics in the courses were most interesting to you?

“Oil industry cartel, and game theory implemented to oil industry, and opportunity cost analysis.”

“I enjoyed learning about the different markets, consumer demand, and patents.”

“Dr. Johnston's personal experiences, and what he had to say about how electric utilities and public utilities commissions work.”

“Utility theory, definition of Want/Need, externalities, etc. Front Curve, Marginal thinking. Value convention/calculation/comparison on Present Value.”

“Econometrics”

“I liked getting to the point that we could discuss actual resource decision making scenarios and trade-offs.”

Which topics in the courses were least interesting to you?

“Economics becomes interesting to me when it starts to look at why things don't work that way, why markets sometimes fail and economic agents often don't act rationally.”

“Complicated details of difference among various markets.”

“I thought that the copy right etc topic should have been covered in the ethics class, not in economics.”

Other comments you have on the EES 810/811 courses.

“I think the role of economics in social and political discourse is an important topic. Is economics a social science which attempts to explain why people act the way they do, as the books often start out by saying? Or is it a prescriptive field of study that guides every kind of policy decision, as it seems to be in practice? This seems especially important in the field of energy. The lines and graphs usually show that social benefit increases with increased consumption and reduced costs. There's a bit of arm-waving about "social costs" that have to be accounted for, but no one can say how big they actually are and the message is that it's just a small correction. They're quite likely not small, and this matters a lot.”

Conclusion

Providing doctoral engineering and physical science students a background in energy and environmental economics has been a challenging but worthwhile endeavor. After having taught the EES 810-811 sequence two times with different instructors, we are getting a handle on how

much content can be taught, what content is most beneficial, and what useful tools (e.g., primer) can be provided to the students. Feedback from the students has been mostly positive including aiding the first graduate of the EES program in getting a permanent job with an environmental consulting company and providing them with a unique experience that they can share with potential employers.

Bibliography

1. North Carolina A&T State University (2008), <http://www.ees.ncat.edu>, Greensboro, NC.
2. Masters, G.M. (2004), Renewable and Efficient Power Systems, John Wiley & Sons, Hoboken, NJ. Sections 3.11, The Regulatory Side of Electric Power; 3.12, The Emergence of Competitive Markets; Section 5, Economics of Distributed Resources.
3. Goodwin, N. (2005), Microeconomics in Context, Houghton Mifflin, Boston, MA. Chapters 1 - 12.
4. Kubasek, N.K., Silverman, G.S. (2005), Environmental Law, Fifth Edition, Pearson Prentice Hall, Upper Saddle River, NJ. Chapter 4, An Introduction to Environmental Law and Policy; Chapter 5, Air Quality Control; Chapter 9, Energy.
5. Pearson, C.S. (2000), Economics and the Global Environment, Cambridge University Press, Cambridge, UK. Part 1, The Basics (first six chapters); Chapter 14 (in Part 3), Economics and Global Warming.
6. Bonello, F.J. (2006), Taking Sides: Clashing Views on Controversial Economic Issues, Twelfth Edition, McGraw-Hill/Dushkin, Guilford, CT. Chapter 15, Are the Costs of Global Warming Too High to Ignore?
7. Rockman, H.B. (2004), Intellectual Property Law for Engineers and Scientists, IEEE Press Wiley-Interscience, Hoboken, NJ. Chapters 1-2, Intellectual property (overview and in business); Chapters 3-8, patent law and the patent application process.