Princeton University
Woodrow Wilson School
Graduate Program

Fall Term - 2005

**Woodrow Wilson School 585b**
**Living in a Greenhouse: Technology and Policy**

**2005 COURSE INFORMATION AND SYLLABUS**

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TUESDAYS, 1:30-4:30 p.m.

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## Course Information

The emphasis of the course is on the solutions to the global carbon problem, rather than the problem itself. Solutions take the form of multiple deep changes in the energy system and, to a lesser extent, in the way we use land. The course will argue that: 1) the global carbon problem can be solved; 2) the world will be changed by doing so; 3) the changes are largely for the good.

The premise of the course is that the global carbon problem has been made more opaque than necessary. The student will be empowered to discuss solutions to the climate-and-carbon problem quantitatively, to assess the promise of new industries, to formulate the policies that could foster these industries, and to envision the campaign strategies that might elicit such policies.

The focus of the course is on the next 50 years. Much of the literature of climate mitigation has been framed by the next 100 years, which exceeds the longest time horizons of business strategy and public policy, thus discouraging concrete discussion. We pose a choice: we can ignore climate change mitigation for 50 years, attending instead to other priorities, but thereby leaving a world for our grandchildren's generation where certain solutions have become impossible and other solutions are much harder to contend with. Alternatively, those alive today have the opportunity to "solve" the carbon problem, in the sense that we can present a carbon management problem to our grandchildren's generation that we guess now will be comparably difficult – neither immensely harder nor much easier.

The focus of this course will be on "mitigation," rather than "science," or "impacts," the other two members of the triad of concerns in the structure that pervades work on the climate problem. Accordingly, the course will treat in depth neither what is being learned about the greenhouse problem (the major sources of uncertainty and how quickly they are being resolved) nor human impacts (climate change, sea level rise, biodiversity degradation, disease).

Although the course has a global, not a U.S. focus, when we look at international mechanisms for carbon management, we will look not only at the Kyoto Protocol, which went into effect early in 2005 without the participation of the U.S., but also at U.S. proposals for a parallel technology-based track.

The course builds on a paper written by the course's professor and Prof. Steve Pacala, (Ecology and Evolutionary Biology, Princeton), published in *Science* in August 2004 ("Stabilization Wedges: Solving the Climate Problem for the Next 50 years with Current Technologies." *Science*, Vol. 305, pp. 968-972, August 13. 2004.) The paper's reception suggests that we have provided a useful way of relating human action to the challenge of climate change.

*Obligations of the students* Because the course has such breadth, it is essential that the student plunges into one or two areas in depth via term papers. There will be a short (6-10 page) and a long (12-20 page) paper. The first will be presented orally in Week Seven, right after the Break. The second will be presented orally in the final week. The second paper may be a deeper discussion of the topic of the first paper, or it may deal with a completely different topic.

One goal of the course is to increase the student's appetite for quantitative reasoning, and to this end there will be occasional problem sets.

The professor teaching this course is also responsible, in the fall of 2005, for Environment 524, a special-topics graduate course administrated by the Princeton Environmental Institute (PEI) that will meet six or seven evenings, generally on Thursdays. The topic this fall is Oil and the Middle East. Enrollment in ENV 524 is strongly encouraged.

The course begins at 1:30 p.m., rather than 1{00 p.m., because the professor is also in charge of the PEI Lecture Series, which is held each Tuesday from 12:20 to 1:20 p.m. in Guyot 10. Lunch is available to lecture attendees immediately preceding the lecture. Students will be encouraged to attend some of these lectures.

## Syllabus, Condensed, Week-by-Week

**Week One:** ***Introduction: The world's new goal of "stabilization" of atmospheric $CO_2$ concentration***

**Week Two:** ***How large is the task of avoiding doubling the Earth's pre-industrial atmospheric $CO_2$ concentration?***

**Week Three:** ***Special topic #1: Depletion of carbon resources***

**Week Four:** ***Stabilization wedges associated with the decarbonization of electricity***

**Week Five:** ***Stabilization wedges associated with the decarbonization of fuels used directly and with the enhancement of biological sinks***

**Week Six: Special topic #2:** ***Consumption and the good life***

***BREAK WEEK***

**Week Seven:** ***Student presentations: First term paper***

**Week Eight:** ***Division of tasks and division of costs in a world of rich and poor***

**Week Nine:** ***The environmental and social costs and benefits of the stabilization wedges: Solution science***

**Week Ten:** ***Special topic #3: International governance and nuclear power***

**Week Eleven:** ***Our problematic destiny: Managers of carbon, managers of Earth***

**Week Twelve:** ***Student presentations: Second term paper***

## Syllabus, Partially Expanded, Week-by-Week

## Note: The material presented here is meant as a guide to discussion.

**Week One: Introduction: The world's new goal of "stabilization" of atmospheric $CO_2$ concentration.**

The Earth in thermal equilibrium, absorbing heat from the sun and radiating it to space. The atmosphere and the greenhouse effect. $CO_2$ concentrations in the past and today. The fossil-carbon source and the land-use source. Terrestrial and ocean sinks.

The carbon problem within the climate problem: aerosols, methane and other greenhouse gases, stratospheric ozone, air pollution. Ecological vs. direct human impacts. The changing ocean. Linear and non-linear change. Are we running an experiment on ourselves? How fast are we learning?

For many, solving the carbon problem, or even solving the climate problem, is a surrogate for other goals: rejection of consumerism, technological elites, and human centeredness; promotion of self-sufficiency; diminishment of networks and concentrations of power. In this course we assume that the problem of solving the carbon problem is worth solving for its own sake.

**Week Two: How large is the task of avoiding doubling the Earth's pre-industrial atmospheric $CO_2$ concentration?**

Stabilization at what level? The answer should depend on both the risks of disruption and the level of effort required to mitigate. The centrality of fossil fuels in global energy supply, and the centrality of the energy problem in the carbon problem

Wait or act now? With delay comes greater knowledge of risks. With prompt action comes the avoidance of further system momentum in counterproductive directions. The usefulness of interim goals. Kyoto goals (2008-2012) vs. mid-century goals.

The "stabilization triangle" as a representation of 1) a 50-year interim goal (*no greater global $CO_2$ emissions in 50 years than today)* consistent with "avoiding doubling" and 2) Business As Usual in the absence of carbon policy. What is the range of reasonable expectations about $CO_2$ emissions in the absence of deliberate carbon policy?

The "stabilization wedge" as a useful decomposition of the stabilization triangle and a useful unit of action. A stabilization wedge is a strategy, using technology already deployed somewhere in the world at industrial scale, that avoids the emissions of one billion tons of carbon per year in 2054 A wedge is a substitution: a less carbon-intensive activity replaces a more carbon-intensive activity.

**Week Three: Special topic #1: Depletion of carbon resources.**

The carbon problem would not deserve to be a global priority if the fossil fuel era were to end with the end of conventional oil and gas. But coal, unconventional oil (e.g., oil sands) and unconventional gas (e.g., methane clathrates) are abundant. Nonetheless, in the near term, there are strong interactions, especially at the level of national energy policy, between the carbon problem and complexities of the global energy system introduced by limitations on the oil and gas supply.

The special problem of oil and the Middle East. Politics may retard investments in the still abundant low-cost oil in the Middle East, leading to rising oil prices and improving the relative competitiveness of all emergent energy technologies. On the other hand, concern for the

geopolitics of oil may accelerate investments into the production of liquid fuels from coal and may also stimulate the scale-up of biofuels.

**Week Four: Stabilization wedges associated with the decarbonization of electricity**

Filling the stabilization triangle with stabilization wedges requires parallel campaigns. No single strategy can provide the required carbon emission reductions. On the other hand, not every available wedge is required. The formulation in terms of parallel campaigns and co-benefits elicits new thinking about collaborations and coalitions.

An end-use perspective on energy use and carbon emissions: transport, power, buildings, industry. Very particular small systems, repeated billions of times, dominate carbon emissions: the house window, the light bulb, the car engine, the electric motor. Historical perspectives and current trends.

Wedges associated with electric power:

End-use efficiency: Using electricity efficiently in lighting, motors, appliances.

Behavioral choices involving reduced use of electricity

Efficient power plants.

Fuel shifts among the fossil fuels (gas power for coal power)

Coal or gas power with carbon capture and storage

Electricity from natural systems that enhance solar energy (hydropower, wind)

Electricity directly from solar energy via high-temperature solar collectors (parabolic troughs and dishes) or photovoltaic collectors

Geothermal power

Nuclear fission power

The demography of capital: Perverse commitment to extensive future emissions from inappropriate power plants.

**Week Five: Stabilization wedges associated with the decarbonization of fuels used directly and with the enhancement of biological sinks**

Wedges associated with fuels used directly.

End-use efficiency: Using fuels efficiently in buildings, vehicles, industrial processes

Behavioral choices involving reduced use of fuels

Efficient extraction and refining of fuels

Biofuels

Decarbonized hydrogen fuel (many sources)

Low-temperature solar thermal energy for space and water heating (flat-plate collectors)

Passive solar architecture

Carbon implications of synthetic fuels from coal or gas

Wedges associated with the substitution of decarbonized electricity for fuels. Such technologies may be elicited if, as it now seems, it is harder to decarbonize fuels used directly than to decarbonize electricity. Examples are plug-in hybrid vehicles and electric heat pumps for space heating.

Wedges associated with the enhancements of biological sinks:

Reduced deforestation and increased reforestation

Deliberate build-up of carbon in soils

Enhancement of the ocean biological sink (e.g., by iron fertilization)

The demography of capital: Perverse commitment to extensive future emissions from inappropriate buildings.

**Week Six: Special topic #2: Consumption and the good life**

The carbon problem is a problem of modernity, a problem of prosperity. It is a byproduct of choices about how to live well: what to consume, how to spend time. Today, it is nearly universally believed, a good life is one lived with exuberance: with a wide variety of experiences. Of great value are privacy, safety, convenience, and excitement. The pursuit of these goals drives resource use upward.

Balancing some of this upward pressure is an emerging negative feedback of prosperity on resource use: the correlation of greater wealth with a desire for fewer children. Global population may soon peak and then fall.

Looming large are the carbon emissions of the world's new arrivals into the "middle class," perhaps another two billion people, no longer living in abject poverty, driving first mopeds and then cars, living in apartment buildings and then detached or semi-detached houses. Patterns of consumption result, in considerable measure, from emulation of the choices of the rich.

Many cultures in the history of the world have defined the good life differently than prosperous people do today. Are serious challenges to the values of the prosperous in view, anywhere in the world?

***BREAK WEEK***

**Week Seven: Student presentations: First term paper**

**Week Eight: Division of tasks and division of costs in a world of rich and poor**

Specific international arrangements for carbon management were embedded in the Framework Convention on Climate Change and the Kyoto Protocol. The world was divided into a group of more industrialized countries and a group of less industrialized countries. Each of the more industrialized countries was assigned a national target. A "clean development mechanism" nominally encourages nations in the first group to invest in carbon management in the second group. Emissions trading is also encouraged.

The Framework Convention and the Kyoto Protocol say little about technology. But in recent years a complementary organizing principle for carbon management is being proposed, focusing more on the technology that needs to be developed and less on the targets that need to be achieved. Several of the first international efforts to develop carbon-responsive technology do not express any bipartite division of the world.

Embedded in the Framework Convention and the Kyoto Protocol is a view that the more industrialized countries have an obligation to act first, because their emissions have dominated global emissions in the past and because their average per capita income levels are higher. This formulation can be criticized for ignoring the consequences for developing countries resulting from their current investments in long-lived capital facilities, like power plants and buildings; if these investments result in relatively wasteful outcomes from the standpoint of carbon emissions, and if a later stage of global carbon policy creates significant costs for carbon emissions wherever they occur, the carbon-emission "commitments" embedded in these investments will generate extra costs far into the future. A contrary formulation calls attention to the merits of "leapfrogging," the development of low-carbon technologies *first* in developing countries, whenever warranted.

The goal of bringing to an end the abject poverty present in developing countries is sometimes perversely presented as being at odds with the goal restricting global carbon emissions. Quantitative argument can establish that bringing the first water pumps, light bulbs, cell phones, televisions, and refrigerators to the two billion people in the world's villages who today are without electricity will scarcely affect the carbon accounts.

**Week Nine: The environmental and social costs and benefits of the stabilization wedges: Solution science**

There are no trouble-free ways to manage global carbon. Although every wedge has co-benefits, generating alliances and improving the prospects of implementation, every wedge also has a dark side, generating opposition and challenges for implementation. Some of elements of carbon-reduction technologies are problematic at the level of individual projects, while others appear only with scale-up to hundreds or thousands of projects.

We suggest a name for the study of the positive and negative features of social and technological changes that accompany the solutions introduced to deal with carbon management: "solution science." We bring solution science to bear on hydropower, on other forms of renewable energy, and on carbon dioxide capture and storage.

**Week Ten: Special topic #3: International governance and nuclear power**

No other energy source generates as much controversy as nuclear power. Nuclear power contributes substantially to electricity production in the United States, Europe, and Japan, but almost no new nuclear power plants are being built. The technology's advocates struggle to regain public confidence, lost after the economic debacle at Three Mile Island and the human tragedy at Chernobyl.

The global expansion of nuclear power may be thwarted by its links to nuclear weapons proliferation, most especially, through the dual-use technologies for uranium enrichment and plutonium recycle. Until very recently, nuclear weapons proliferation was a far less salient issue in nuclear power politics than reactor siting and safety and radioactive waste disposal. This is changing, especially as events unfold in Iran that draw attention to the civilian-military couplings inherent in nuclear power. Iran is nominally playing by the international rules governing nuclear power embodied in the agreements administered by the U.N.'s International Atomic Energy Agency. The world's responses suggest that these rules need to be changed.

One can insist on a global nuclear power system with one set of rules for some countries and a different set of rules for others. Or one can maintain the criterion of universality and find new universal rules; probably, this will mean compromising sovereignty in all countries.

Nuclear fusion power shares most of the problems of nuclear fission power. A world incapable of creating globally thriving nuclear-fission power is unlikely to create a globally thriving nuclear-fusion power.

**Week Eleven: Our problematic destiny: Managers of carbon, managers of Earth**

What is our role on the planet, looking forward and beyond 2055? The Framework Convention on Climate Change envisions our perpetual engagement in carbon management in order to achieve and maintain a constant concentration of carbon dioxide in the atmosphere. What sort of goal is this, and how might it generalize?

"Stabilization" is a word from control theory. The climate regime currently envisioned is a world where human beings actively control the composition of the atmosphere. We are placing ourselves in the role of managers of the Earth – first of all, for our own benefit, but also, to some extent, for the benefit of other forms of life. Using another word that captures this new role for our species, we are about to become "geoengineers."

The cultural implications of active management are very different from those of minimizing the human impact on natural system, which has been the objective of much of environmentalism. Active management creates challenges to democratic processes within and across countries: by what processes will decisions be reached about ends and about means?

Implicit in active management of the Earth is a planetary consciousness – an affinity greatly enlarged, relative to the tribalism and nationalism of the current day.

**Week Twelve: Student presentations: Second term paper**

## Books to be Placed on Reserve

Deutch, John and Richard K. Lester, *Making Technology Work: Applications in Energy and the Environment.* Cambridge University Press, 2004

Deutch and Lester have written a set of case studies dealing with topics addressed in the course. book. The emphasis is on teaching the techniques of the policy analyst to the undergraduate engineer.

International Energy Agency, *World Energy Outlook 2004*. Paris, France: OECD/IEA

The projections for the world energy system, typically twenty five years into the future, published by the International Energy Agency in its biannual World Energy Outlook, are cited by the energy industries and frame their worldview.

Parson, Edward A., *Protecting the Ozone Layer: Science and Strategy*. Oxford University Press, 2003

Parson conducted hundreds of interviews on the way to a book of deep scholarship about the formation of a regime of global management of stratospheric ozone. There are important parallels between ozone and $CO_2$,

Smil, Vaclav, *Energy at the Crossroads: Global Perspectives and Uncertainties*. MIT Press, 2003.

Smil's book is an excellent overview of "energy."

Speth, James Gustav, *Red Sky at Morning: America and the Crisis of the Global* Environment. Yale University Press, 2004

Speth has written a call to action. He identifies new routes to policy innovation, by providing a fresh perspective on the relationship between government and civil society.

Tester, Jefferson W., Elisabeth M. Drake, Michael J. Driscoll, Michael W. Golay, and William A. Peters. *Sustainable Energy: Choosing Among Options*. MIT Press. 2005.

Just out, this tome is a comprehensive quantitative introduction to energy technologies, with extensive discussion of non-technical issues.

Trefil, James. *Human Nature: A Blueprint for Managing the Earth – By People, For People*. Times Books, 2004

Trefil, a prolific science writer, has written an affirmatively non-technical book. He unifies a presentation of genomics, biodiversity, and the greenhouse problem with an argument that new knowledge is providing human beings with an unprecedented capacity to manage the natural world. His chapter on the greenhouse problem deals with the ambiguities of climate science but not with the technologies, policies, and lifestyle dimensions of carbon mitigation.

Weart, Spencer. *The Discovery of Global Warming.* Harvard University Press, 2003.

Weart, a historian of science, tells a story of many small steps and lots of wrong turns.

## Useful Websites


BP, 2003. *BP Statistical Review of World Energy*

http://www.bp.com/subsection.do?categoryId=95&contentId=2006480

Energy Information Administration, U.S. Department of Energy, 2004. *International Energy Annual 2002*.

http://www.eia.doe.gov/emeu/iea/contents.html

Energy Information Agency, U.S. Department of Energy, 2004. *International Energy Outlook, 2003*. Report # DOE/EIA-0484.

http://www.eia.doe.gov/oiaf/ieo/index.html.

Gale, J. and Y. Kaya, eds., 2003. *Proceedings of the 6th International Conference on Greenhouse Gas Control Technologies, 1-4 October, 2002, Kyoto, Japan.* Two volumes. Amsterdam: Pergamon.

http://www.ieagreen.org.uk/ghgt6.htm

International Energy Agency, 2002. *World Energy Outlook 2002*. Paris, France: OECD/IEA. By subscription:

http://library.iea.org/dbtw-wpd/Textbase/nppdf/stud/02/weo2002_1.pdf.

International Energy Agency, 2003. *Key World Energy Statistics. 2003*.

http://www.iea.org/dbtw-wpd/bookshop/add.aspx?id=144

Intergovernmental Panel on Climate Change, 2000. *Land Use, Land Use Change and Forestry.* R.T. Watson et al. eds. Cambridge University Press.

http://www.grida.no/climate/ipcc/land_use/index.htm

Intergovernmental Panel on Climate Change, 2001. *IPCC Third Assessment Report—Climate Change 2001*. Cambridge University Press.

http://www.ipcc.ch/index.html

IPCC, 2001. *Special Report on Emissions Scenarios*.

http://www.grida.no/climate/ipcc/emission/index.htm

National Research Council, 2004. *The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs*. Washington, D.C., National Academy Press.

http://www.nap.edu/books/0309091632/html/