Undergraduate Courses Fall 2012

Architecture

48-300 Architecture Design Studio: Environment
Design Studio III: Building and Site is a required course taught in the third year. The subjects of the Third Year Fall Semester are the reciprocal orders of buildings and landscapes and the development of the building site. The work builds on knowledge gained in prerequisite and co-requisite courses including 48-312 Site Engineering. This course asks students to continue their investigations into the formal and spatial composition and enquiries of previous semesters with a focus on the following concepts: Occupancy: Social and cultural phenomena, dimension/measurement and cycles of time relating to human and non-human occupancy Site assessment: site inventory at many scales Grading and surface manipulation: compatibility of grading with related technical considerations for water management, ground structures, surfacing, plants, and maintenance Road alignment: design of roads and parking to support construction, service and the anticipated occupancies, design of roads to connect to other roads with appropriate sight lines, stack spaces, and turning requirements, layout and sizing of parking spaces for vehicles Storm water: volume and direction of runoff water on both the undisturbed and developed areas, storm water surface system, Plants: selection of plants and plant communities with consideration for regional, local, and site-specific factors.

48-315 Environment 1: Climate and Energy
This course introduces architectural design responses for energy conservation, human comfort, and the site-specific dynamics of climate. Students will be expected to combine an understanding of the basic laws of comfort and heat flow with the variables of local climate to create energy design guidelines for their own work. The state of the art in building energy conservation and passive heating and cooling technologies will be presented, with take-home readings and assignments. To stress the significance of architectural design decision-making on energy consumption and comfort, full design specifications and calculations will be completed for a residential-scale building. Students will compile a professional energy consultant's report, designing the most viable energy conservation retrofit measures for their client from siting, massing, organization, enclosure detailing, opening control, to passive system integration and management. An overview of world energy consumption in buildings and energy design standards will be challenged by lectures on building energy conservation successes, and emerging demands for a broader definition of sustainability. The course will end with a focus on the design integration of natural conditioning systems and the potentially dynamic interface of mechanical systems in small- and large-scale buildings.

48-412 Environment II: Mechanical Systems
Mechanical Equipment is a study of the mechanical systems required to heat, cool, ventilate, wire and plumb a building. Students will focus on energy usage and savings for buildings along with a look at the various system types and equipment used – past, present, and future. The course parallels the AIA review class for the professional license examination, and should become a future study guide for the exam.

48-431 Bio Logic Responsive Building Technology
The intent of this course is to transfer knowledge from biology and ecology to the field of architecture and thereby better understand the porous boundaries between living and non-living systems. Through the lens of responsive material sets and digital fabrication technologies, students work in multidisciplinary teams to develop responsive building technologies that operate in accordance with the biologic condition of homeostasis— the ability for an organism to maintain equilibrium in response to fluctuating environmental conditions. The outcomes are working models that demonstrate responsive behavior to environmental fluctuations. Once groups are formed, I work with each team to structure a design-research project based on their skill sets. The course is a creative and intensive open-source collaborative workshop where models are constructed and tested during class time. Open to students of any discipline, no previous design experience is required, simply a sustained commitment to transferring your knowledge stream to the design of the built environment.

48-453 Urban Design Methods
This undergraduate lecture course introduces urban design history, theory and methods. It is a required supporting course for the Urban Laboratory design studio, and similarly examines urban design at multiple scales: city form and networks, neighborhoods and block structures, streets, public spaces, and urban building typologies. Key issues introduced include the

emergence and evolution of urban design as a discipline, economic, social and political factors affecting the contemporary city, and environmental sustainability at the urban scale. A wide variety of cities, projects, proposals and methodologies are examined. Assignments include readings from seminal texts, quizzes, and a final examination.

48-728 Special Topics in BPD: Redesigning Our Built Environment

The course includes an overview of various real life concepts to implement "Value Added Propositions" for buildings. The goals are to: 1. Provide energy efficient and sustainable designs and processes for existing residential, educational and office buildings. 2. Gain basic understanding of building science, renovation technologies, and techniques used in today's construction industry. 3. Learn how a scope of work is developed for a Green Building through building diagnostic techniques and energy modeling. 4. Examine energy efficiency financing opportunities. Students will work with industry, manufacturers, and government to help identify the challenges and barriers facing the industry and provide new efficient solutions and strategies.

48-738 Special Topics: Ecological Footprints

The Ecological Footprint is a measure of the demand that human activity puts on the biosphere. More precisely, it measures the amount of biologically productive land and water area required to produce all the resources an individual, population, or activity consumes, and to absorb the waste they generate, given prevailing technology and resource management practices (Global Footprint Network 2010). This course will engage students in the metrics and impacts of our collective consumption and waste of: -Energy -Materials (Cradle to Cradle) -Food -Water -Transportation -The Integration of Systems towards Quality of Life Starting at the global context, this course will address challenges/opportunities to advance regenerative practices, improving our relationship to nature. Learning from international best practices, we will continue to explore ecological footprints at the global, national, regional, city, neighborhood, building and individual scale. The course will be based on lectures and readings, with assignments and student presentations to fully explore each of the footprint characteristics. Experts on water, energy, materials, food and other resources have been invited to lecture. By mid semester, an application project will be selected for ecological footprint analysis and the development of design, engineering, and operational guidelines towards reducing that footprint. The potential application projects include: the CMU campus footprint and Donner House retrofit; the Energy Innovation Center and education of the trades in reducing our regions footprint; or a new Net Zero building for Carnegie Mellon University. This will be a collaborative effort.

Art

60-203 Concept Studio: Eco Art

An interdisciplinary studio course that provides an introduction to an art practice focused primarily on ecology and the environment. Combines the exploration of the history of environmentalism and ecological art with the production of creative projects to address related issues such as sustainability. Shorter initial exercises and collaborative projects will precede and evolve into larger and more extended individual and/or collaborative projects. Considers both indoor and outdoor sites with an emphasis on context and the use of natural and recycled materials. Open to freshman and sophomores in the School of Art and to students in other disciplines.

Biological Sciences

03-126 Cellular Response to the Environment

This laboratory course provides a multifaceted view of the cell, with the opportunity for new discovery, through microscopic imaging of a cell's response to environmental changes. We will identify yeast gene products that undergo changes in expression or subcellular localization after simple environmental perturbations or drug treatments. Students will be trained in basic molecular biological methods, including recombinant DNA manipulation, and basics of functional genomic resources. Enrollment is limited to first-year students in MCS. Special permission required.

Business Administration

70-332 Business, Society and Ethics

The course draws upon actual cases to explore fundamental questions faced by businesses operating in the United States and elsewhere in the world. What justifies governmental regulation of your business? What are the rights of employers and employees? How does the law protect consumers? What laws protect the environment? How do you choose the best legal form for your business? What are the lines of power within a corporation? What protections are available to shareholders? How do the antitrust laws protect competition? What responsibilities does a business have to the community in which it operates? What is the ethical foundation on which business ought to be conducted? The course puts businesses in their legal and ethical context.

70-376 Energy Systems

This course will provide students with an understanding of the systems and markets that provide energy to businesses and consumers. Students will be introduced to the sources and uses of energy, and how they have evolved and the possible paths over which they may evolve in the next decades. The course places an emphasis on electric energy, the single largest energy source in many industrial economies, but also covers natural gas, oil, and selected other primary energy sources. Students will learn the energy flows in the USA and the world, as well as the business-relevant characteristics of the engineered systems that provide the energy in various forms. Both traditional and emerging energy sources will be discussed, and students will understand the difference between an energy carrier and an energy source. We will also discuss some of the issues that arise without proper management of the physical risks of energy systems. Students will learn some of the history of electric power regulation and the inconsistent subsidy structures that have provided opportunities and challenges for energy companies and investors, including discussion of how emissions restrictions affect fuel, engineering, investment, and project finance choices. The history of electric power markets will be discussed, with an eye to examining the opportunities that market changes create for business.

Chemistry

09-426 Environmental Decision Making

This course will cover a number of topics in environmental decision making, including risk perception, risk communication, risk ranking, multi-attribute utility theory, decision analysis, the "precautionary principle," the economics of environmental externalities, commons dilemmas, cost-benefit analysis, the valuation of health and environmental amenities, discounting, intergenerational equity, environmental justice, and sustainability.

Civil & Environmental Engineering

12-100 Introduction to Civil and Environmental Engineering

Introduction to selected subfields in the discipline, such as structural engineering, construction project management, and environmental engineering. Problem-solving exercises apply fundamental concepts from these subfields to integrate the steps of analysis, synthesis, and evaluation through individual homework assignments and group projects that require attention to a broad range of issues. The course also exposes the students to issues related to engineering practice such as working in teams, scheduling, evaluating risk and making ethical decisions. In addition to regular lectures and project exercises, the course includes guest speakers and class demonstrations.

12-401 Civil and Environmental Engineering Design

Methodology for formulating and solving design problems, characterized by incomplete specifications, open-ended solution space, and partial evaluations. The methodology is illustrated and applied in the context of realistic design problems drawn from civil and environmental engineering. Design projects performed by teams, emphasizing collaborative problem-solving and

preparation of written and oral reports. The importance of ethics, lifelong learning, and professional licensure are also discussed. Senior Standing in Civil and Environmental Engineering or instructor approval for Design Minors.

Electrical and Computer Engineering

18-418 Electric Energy Processing: Fundamentals and Applications
This course provides an introduction to the fundamentals of electrical energy conversion and its use in several real-life systems. The course starts with a brief review of general mathematical and physical principles necessary for subsequent study of electrical energy conversion applications. This includes modeling, analysis, and control of general physical systems in time and frequency domain. Since the focus of energy conversion methods studied in this course is from electrical to mechanical systems, special attention is paid to electromagnetic theory. Rotating machines theory is developed and intuitively explained starting with Maxwell equations and analyzing general static and dynamic electromagnetic circuits. Power electronics methods are also introduced because most of modern electrical systems employ such methods. At this point, the necessary background is gained to analyze real life electrical energy conversion systems. We will focus on automotive, airplane, space station, and sea power systems. The main focus will be on operational principles and when appropriate stability issues of particular implementations. Time allowing, dynamic problems with interconnecting such systems will be briefly introduced and possibly studied by curious students in their course projects.

18-587 Electrical Energy Conversion, Control and Management
This capstone course helps the students fully appreciate their acquired knowledge by working on semester-long projects in the area of electrical energy conversion systems, their control and management. This course will draw on engineering background in control systems, computer engineering, telecommunications, digital signal processing, power electronics and power systems. The students can choose from a list of recommended projects or propose their own projects relevant to power generation, energy management, power quality control, communication security, renewable generation, environmental issues, and other similar problems. Students will go through a real life product development cycle from identifying the need for a solution, producing the specifications, designing and simulating it, and finally implementing it. Lectures provide supplemental discussions of simulations, planning, progress reporting, using available resources, and general project management from the beginning to the end. Lectures will also address engineering ethics, standard and open source and hardware intellectual property rights and copyright laws in general.

Engineering and Public Policy

19-424 Energy and Environment
This course will explore the relationships between environmental impacts and the utilization of energy through a series of case studies on topics of current interest. Such topics might include the use of renewable and non-renewable fuels for electric power generation; energy use for automobiles and other transportation systems; energy use for buildings and industrial processes; and environmental issues such as urban air pollution, ozone formation, acid rain, and global warming. The emphasis will be on analysis of energy-environmental interactions and tradeoffs, and their dependency upon engineering design choices, economic variables, and public policy parameters. Junior or Senior standing in CIT or permission of instructor.

19-426 Environmental Decision Making
This course will cover a number of topics in environmental decision making, including risk perception, risk communication, risk ranking, multi-attribute utility theory, decision analysis, the "precautionary principle," the economics of environmental externalities, commons dilemmas, cost-benefit analysis, the valuation of health and environmental amenities, discounting, intergenerational equity, environmental justice, and sustainability.

19-440 Combustion and Air Pollution Control
Formation and control of gaseous and particulate air pollutants in combustion systems. Basic principles of combustion, including thermochemical equilibrium, flame temperature, chemical kinetics, hydrocarbon chemistry, and flame structure. Formation of gaseous and particulate pollutants in combustion systems. Combustion modifications and post-combustion technologies for pollutant control. Relationship between technology and regional, national, and global air pollution control strategies. The internal combustion engine and coal-fired utility boiler are used as examples.

English

76-319 Environmental Rhetoric
How people think and talk about the environment matters; it reveals what they value and shapes what they do. We will look at how competing discourses define man's relationship to the natural world, frame environmental problems, and argue for public action. As we compare the environmental rhetoric of naturalists, scientists, policy makers, and activists, we will trace an American history that has managed to combine mystical celebration with militant critique, and scientific research with public debate. Equally important, this course will prepare you to act as a rhetorical consultant and writer, studying how writers communicate the three "Rs" of environmental rhetoric: relationship with nature, the presence of risk, and the need for response.

76-476 Rhetoric of Science
Rhetoricians study how strategic use of language and argument contribute to the development of scientific knowledge and how science is communicated and argued within the technical and the public spheres. In this course, we will examine various aspects of scientific communication including scientific audiences, visuals, and conventions for argument. In particular, we will explore the questions: What happens to scientific information and argument when they move from specialist journals into the mainstream media? In what ways might emotion and the character of the scientist influence scientific debates? What role do metaphor, analogy, and other stylistic features play in developing scientific thought and argument? And what role do visuals play in arguing science? To investigate these questions, we will be examining a broad range of real-world discourse from scientific journals to mainstream media and engaging with a broad range of scholarship in rhetoric, sociology, anthropology and philosophy of science. Whether you have a background in science or not, this course is designed for anyone interested in learning more about the practices and challenges of scientific communication and argument.

History

79-104 Global Histories: People Processes and Environment
Human activity transcends political, geographical, and cultural boundaries. From wars to social movements, technological innovations to environmental changes, our world has long been an interconnected one. Acquiring the ability to understand such transnational and even worldwide processes is an indispensable part of any college education. This course provides students with an opportunity to develop the skills and perspectives needed to understand the contemporary world through investigating its global history. A variety of sections are offered in order to give students the opportunity to choose between different themes and approaches. All sections are comparable in their composition of lectures and recitations, required amounts of reading, and emphasis on written assignments as the central medium of assessment. The sections all aim to help students: (1) master knowledge through interaction with the instructors, reading material, and other students, (2) think critically about the context and purpose of any given information, (3) craft effective verbal and written arguments by combining evidence, logic, and creativity, and (4) appreciate the relevance of the past in the present and future.

79-289 Animal Planet: An Environmental History of People and Animals
Why do modern societies go to great lengths to protect some animals and slaughter others? How do people use animals to demarcate boundaries among themselves and between "humans" and "nature?" What are the environmental ramifications of

domestication? Do animals make history? These are some of the questions that we will seek to answer as we explore the role of human--animal relationships in making the modern world (ca. 1400-present). We will examine some of the myriad ways in which people and animals have interacted with a focus on both the ecological significance of these relationships and the often-contradictory meanings that people inscribe on animals. Course readings and visual materials will be drawn from many parts of the world. Evaluation will be based on active participation in class discussions, weekly field notes, and a final assignment focused on visual representations of people and animals.

79-372 Perspectives on the Urban Environment

This course will explore the interaction of cities, technology and the natural environment over time. In doing so it will consider major issues confronting cities today including landscape and site changes; water supply, wastewater disposal and flooding; solid waste disposal; transportation and suburbanization; energy changes; and the impact of deindustrialization. These themes will be approached through a combination of class discussions, lectures, and visiting speakers. Class participation is expected, and will comprise a portion of the grade. In addition to required texts, readings will be distributed on Blackboard.

79-374 American Environmental History: Critical Issues

This course explores critical issues in the history of the American environment during the last three centuries. Among the specific topics to be covered are changing attitudes toward nature; forms of rural and urban development and environmental effects; the impacts of technology and industrialism; the conservation and environmental movements; and environmental problems and prospects today.

79-375 China's Environmental Crisis

In the context of China's changing ecology, this course explores whether and how sustainable development has been, is being, and might be pursued by its vast population and political leadership. Without neglecting culture--e.g., Confucian, Daoist, Buddhist and Altaic (steppe) views of ideal human/environment interaction--we trace historical demographic patterns and their effects on China's fauna and flora, and investigate past government efforts at water control, migration, new crop introduction, natural disasters, etc. Over half of the course concerns the People's Republic (1949-), paying special attention to birth control policies, the steppe reclamation, the Three Gorges dam, industrial growth, pollution scandals, tourism and environmental policy. We work mostly by discussion, centering on materials read in advance by class members.

79-381 Petrocultures: How Oil Changed the World

Few things have changed the world as much as petroleum: cars, airplanes, fertilizers, plastics are just some of the technologies derived from oil. Moreover, the wealth and power associated with "black gold" has shaped geopolitics in the twentieth century, giving rise to so-called "petro-states." For the first five weeks, we will trace the evolution and expansion of "petrocultures" around the world. The remainder of the course will be organized around individual student research projects. The major learning objective of this course is to give students experience writing an original research paper. Students will be expected to define a research question, assemble a bibliography of sources, write and revise an analytical paper, and do an oral presentation. This course, open to all students, partially fulfills the Theoretical and Topical Core course requirement for Global Studies majors.

79-384 Garbage Gone Global: Managing Surplus, Waste, and Desire

In this course, we will use readings and film to explore a variety of issues related to the production, classification, and management of waste. Topics to be covered include the environmental impacts of different waste disposal techniques, the global trade in used and discarded materials, garbage as a source of work and the way gender influences who does this work, the history and current structure of the waste disposal industry in the US and in other places around the world, and practices of recycling and scavenging. Throughout we will pay attention to the different ways we as humans think about, care for, and ultimately discard our material things. Class time will be dedicated to discussion, and students will complete weekly short assignments and a research paper.

Mechanical Engineering

24-424 Energy and the Environment
Fuel cycles for conventional and non-conventional energy resources; relationships between environmental impacts and the conversion or utilization of energy; measures of system and process efficiency; detailed study and analysis of coal-based energy systems including conventional and advanced power generation, synthetic fuels production, and industrial processes; technological options for multi-media (air, water, land) pollution control; mathematical modeling of energy-environmental interactions and tradeoffs and their dependency on technical and policy parameters; methodologies for energy and environmental forecasting; applications to issues of current interest. Junior or Senior standing in CIT or permission of instructor.

Philosophy

80-226 Revolutions in Science
Contemporary science emerged in the 17th century from a series of dramatic innovations in theory and method that has come to be called the Scientific Revolution. Since then, science has been punctuated by repeated 'revolutions' in which scientists have been forced to select among dramatically different frameworks for explaining the world: is the Earth or the sun at the center of the solar system? Do kinds of organisms develop from other kinds, or is each created independently? Is matter infinitely divisible or are all things made of atoms in a void? The way scientists choose one framework over another can tell us something about the nature of science. In this course, we will focus on episodes of scientific change to gain insight into a range of questions: Is scientific change governed by a single method or does each new revolution involve the invention of a new scientific method? How do scientists argue for the existence of unobservable processes, properties, or objects like atoms? In what way do these arguments differ from those of their ancient predecessors? What makes them compelling? We'll begin our investigation by examining the overthrow of ancient Greek astronomy and physics by Galileo, Kepler, and Newton. We will then turn to a number of subsequent revolutions in other areas of science such as chemistry, geology, and evolutionary biology. Students will work with original texts by Galileo, Newton, Darwin, and others.

80-447 Global Justice
Until recently, the dominant view of international relations among both academics and politicians was that governments and citizens of one country have no moral or legal obligations to anyone beyond their own borders. The latter half of the 20th century has seen a dramatic change in this attitude, with a much greater willingness to recognize that demands of justice may transcend national borders and bind different states and their people. This course examines this shift through the lenses of history, philosophy, law, politics, and anthropology. It is being offered in conjunction with the 2009-2010 Humanities Center Colloquium Series on "Global Connections, Global Responsibilities." Topics covered include: theories of justice; sovereignty; the universality of human rights; global inequality and poverty; trade and labor in the global economy; climate change; humanitarian intervention and just war; post-conflict reconciliation and social reconstruction; as well as the emergence of transnational modes of governance. In addition to several short writing assignments, students will have the opportunity to carry out a research project on a relevant topic of their choice.

Social and Decision Sciences

88-352 Environmental Economics and Policy
The course will introduce students to the economic analysis of problems associated with private and collective use of environmental resources and to the analysis of public policy options to environmental problems. Policy relevant examples will be used throughout the course. When thinking about protecting nature environmental economics has traditionally focused on the idea that market failure (externalities, non-rival goods, asymmetric information) is the critical source of economic inefficiency. Based on this idea economists have designed policies for environmental protection, which include Pigouvian taxes, marketable permits, liability rules and mechanisms design. We will start from the theories of externalities, market failure and

mechanism design, and we shall explore the causes of these problems and some of the potential remedies using the competing/complementary lenses of traditional and behavioral economics. To organize and evaluate alternative environmental policy options environmental economics has traditionally used rational choice theory. According to rational choice theory, people respond to policy instruments in their own self-interests and take all possible consequences into account. Behavioral economics has emerged to challenge this traditional view by documenting how people make choices and state values that deviate from the conventional rationality model. We will try to understand the behavioral economics underpinnings of environmental policy and how understanding the success and failure of conventional economic theory can help make good environmental policy better.

88-412 Economics of Global Warming

The scientific community has concluded that human industrial activities are causing global temperatures to increase. Coping with the environmental, economic, and political consequences of this change is considered by many to be the preeminent public policy challenge of the 21st century. In this course, we will investigate the basic science of climate change, the prospective economic impact of global warming, the uncertainty involved in long-run climate forecasting, and the technological alternatives available to us as we seek to mitigate the impact of human industrial activity on global warming. The heart of this course will be an in-depth analysis of the policy options available to the United States and the global community. We will investigate the economic costs of these options and the way political realities are likely to shape and constrain policy at the national and international levels.

Carnegie Mellon University - Campus Wide Studies

99-238 Materials, Energy and the Environment

The survival of humans and the advancement of civilization and culture are a result of mankind's continued development of materials. From early times, civilizations with the most advanced materials have dominated the history of warfare and have been responsible for the infrastructural developments that have cradled out societies. As a result, materials have been influential in the trade and commerce between societies and are still to this day, strongly involved in the political, economic and social conflicts worldwide. Materials do not stand alone in development however, they are a result of, or are influenced by, technological needs and developments. The more advanced the material, the more energy and effort is required for its' production. In the US, the production of materials accounts for about 90% of the country's energy usage. This fact clearly indicates a strong tie between materials and energy, and without energy, technological developments based on material advancement will not occur. In our world today, the need to provide improved performance, economics and design in consumer goods comes as a direct result of the market conditions established by consumers. Material selection and design therefore is driven by application and consumer needs which implies that the consumer has a large influence on material consumption. Material selection and material usage in turn have major ecological implications in energy, material resources and direct environmental impact. Awareness of the complicated interaction is paramount for continued development of civilization. With the scale of industrialization that exists on our planet, consideration of resource management, ethical material selection choices, energy management, and final disposal are all necessary to ensure a sustainable future.

Graduate Courses Fall 2012

Architecture

48-729 Productivity, Health, and the Quality of Buildings

Given the growing demand for green buildings by federal and private sector clients, professional practices are tooling up all over the world to deliver high performance, environmentally responsive, 'green' buildings and communities. However, investments in green, high performance building solutions and technologies are still limited by first cost decision-making, and life cycle tools are still largely inaccessible to professionals. A building investment decision support tool 'BIDS' - continues to be developed by the Center for Building Performance and Diagnostics at Carnegie Mellon University, with the support of the Advanced Building Systems Integration Consortium. This cost-benefit decision support tool presents the substantial cost-benefits of a range of advanced and innovative building systems designed to deliver privacy and interaction, air quality,

ergonomics, lighting control, thermal control, network flexibility, and access to the natural environment - from field case studies, laboratory studies, simulation studies, and other research efforts. This course will explore the relationship of quality buildings, building systems, and land-use to productivity, health, well-being and the environment. The course will engage students in the literature that relates building design decisions to ten cost/performance impacts: energy, facilities management, organizational change, technological change, attraction/retention (quality of life) of employees, individual productivity, organizational productivity, salvage/ waste, tax/ insurance/ litigation, and health.

48-731 Sustainable Design Synthesis Prep

This is the preparatory course for the synthesis project course in the Master of Science in Sustainable Design (MSSD) program. Students will build upon the Research Models and Methods class to develop an individual project proposal in an area of their interest related to sustainable design. The students will attend bi-weekly meetings with the instructor and will submit a formal research project proposal at the conclusion of the semester including an abstract, a research plan, a schedule, an annotated bibliography and proposed deliverables.

48-732 Sustainable Design Synthesis

Sustainable Design Synthesis II This is the synthesis project course in the Master of Science in Sustainable Design (MSSD) program in the School of Architecture at Carnegie Mellon University. This course deals with synthesis in solving sustainable design problems using the tools, theories and methods studied in the prerequisite courses. Students will attend weekly meetings with the instructor, conduct the proposed research, submit a final written report and make a presentation of their project in a public forum. Nine-Month Program: Students will build upon the Research Models and Methods class to finalize an individual project proposal in an area of their interest related to sustainable design. Prerequisites: 48-711, 48-722, 48-737, 48-752 or approved equivalents plus one selective. Co-requisites: 48-723 or approved equivalent plus two electives. Twelve-Month Program: Students will complete the proposed project developed and approved in the Sustainable Design Synthesis I course.

48-738 Special Topics: Ecological Footprints

The Ecological Footprint is a measure of the demand that human activity puts on the biosphere. More precisely, it measures the amount of biologically productive land and water area required to produce all the resources an individual, population, or activity consumes, and to absorb the waste they generate, given prevailing technology and resource management practices (Global Footprint Network 2010). This course will engage students in the metrics and impacts of our collective consumption and waste of: -Energy -Materials (Cradle to Cradle) -Food -Water -Transportation -The Integration of Systems towards Quality of Life Starting at the global context, this course will address challenges/opportunities to advance regenerative practices, improving our relationship to nature. Learning from international best practices, we will continue to explore ecological footprints at the global, national, regional, city, neighborhood, building and individual scale. The course will be based on lectures and readings, with assignments and student presentations to fully explore each of the footprint characteristics. Experts on water, energy, materials, food and other resources have been invited to lecture. By mid semester, an application project will be selected for ecological footprint analysis and the development of design, engineering, and operational guidelines towards reducing that footprint. The potential application projects include: the CMU campus footprint and Donner House retrofit; the Energy Innovation Center and education of the trades in reducing our regions footprint; or a new Net Zero building for Carnegie Mellon University. This will be a collaborative effort.

48-752 Zero Energy Housing

Zero energy design and construction has evolved from concept to policy and from single pilot examples to full neighborhood developments. Yet on an annual basis, many zero energy buildings do not achieve their net zero balance. What does it take, technically, to achieve net zero and what else, beyond technical requirements, advances or impedes a net zero future? 48-752 is a graduate level class that explores net zero energy design and construction in the residential sector. Through building science literature, case studies and applied projects, we'll explore what it takes to achieve quantitative net zero in residential buildings and neighborhoods while maintaining occupant comfort and satisfaction. We'll also compare our strategies to requirements in US codes and rating systems to evaluate their impact in moving the US residential sector toward much higher performance buildings. Although our focus is residential, many of the concepts and strategies we cover have parallels in the commercial sector. Students who enroll in the class must know how to calculate without software heat loss and heat gain for a small building. You are also expected to have a fundamental understanding of residential design and construction, plan reading and mechanical systems; US residential materials and construction methods for net zero will be covered in class. Students who

successfully complete this course will understand the components of residential energy consumption, will be able to quantify how various design and conditioning strategies affect energy consumption, will have a fundamental knowledge of renewable energy systems and how to size them for residential use, will be able to identify current energy-related standards and guidelines for US residential buildings, and will be familiar with a wide variety of references and information sources for future use.

48-795 LEED Buildings and Green Design Concepts

LEED, Green Design and Building Rating in Global Context is a graduate level mini-course that examines holistic, integrated strategies for sustainable building design, construction and operation. The course is organized within the framework of the US Green Building Council's Leadership in Energy and Environmental Design (LEED) Rating System: location, site, water, energy, materials, and the interior environment. Within that framework, we explore strategies promoted within LEED and compare/contrast them with strategies in the rating systems of other countries. We also consider additional ways to encourage development of better buildings, e.g., codes and standards, incentives, and project delivery methods. The course focuses on the concepts underlying rating system credits, the national contexts that can produce different rating systems, and substantive improvement in building performance. This course provides the foundation for taking USGBC's LEED Green Associate exam. More importantly, students who successfully complete the course will understand buildings? Powerful impact on the environment and equally powerful strategies to address those impacts. There are no prerequisites for this course. However, because the course moves quickly and we are discussing improvements to building practice, a basic knowledge of the vocabulary, design, construction and operation of buildings is assumed.

CIT Interdisciplinary

39-610 Energy Conversion and Supply

This is the first course in the ESTP core mini-course sequence where master's students learn the basic workings of the systems that supply, distribute, and utilize energy. This class will consider fossil energy, nuclear energy, and renewable energy resources. The course will provide some basic thermodynamics and will cover both conventional and emerging energy conversion technologies. Specific technology examples may vary from semester to semester selected from such important topics as photovoltaics, fuel cells, carbon sequestration and biofuels.

Civil & Environmental Engineering

12-629 Environmental Microbiology for Engineers

This class provides a general introduction to microorganisms in natural and engineered environments. Selected topics include: cellular architecture, energetics and energy conservation, growth and catabolism; evolution and genetics; population and community dynamics; water and soil microbiology; biogeochemical cycling; biofilms; and microorganisms in wastewater, pollution attenuation, and bioremediation.

12-651/127 Air Quality Engineering

The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines.

12-702 Fundamentals of Water Quality Engineering

This course is a systematic overview of water quality engineering designed for students with no prior civil and environmental engineering background. Topics examined include physical, chemical, and biological characteristics of water; common water pollutants; basic water chemistry and microbiology; mass and energy balances and their use in reactor analysis; physical, chemical and biological processes affecting natural water quality and the use of these processes in water supply and wastewater management systems; and selected problems in surface water and groundwater quality management. A background in college-level general chemistry, physics, calculus, and differential equations is assumed.

12-712 Introduction to Sustainable Engineering

This course begins with an overview of the concept of sustainability, including changing attitudes and values toward technology and the environment through the twentieth century. Models for population growth, global food production, and global water resources are then presented, and current problems such as land use, urbanization, and energy and material resources are discussed. Models of industry based on life sciences are then explored, and tools for sustainable engineering are presented. These tools include metrics of sustainability, principles of design for the environment, methods for pollution prevention, and use of mass and energy balances in the design of sustainable systems. Prerequisite: senior/graduate standing in engineering or permission of the instructor.

12-713 Industrial Ecology and Sustainable Engineering Design

This course uses the context established in 12-712 to explore the solution space of engineers in tackling basic problems facing human civilization. The course begins with the concept of a system, using the earth's life support systems as examples. The potential damage of conventional engineering decisions on these life support systems is discussed. Models of industry based on life sciences are then explored, and tools for sustainable engineering are presented. These tools include metrics of sustainability, principles of design for the environment, methods for pollution prevention, and use of mass and energy balances in the design of sustainable systems. Finally, the principles and tools of sustainable engineering are used to explore solutions to some of the most challenging problems identified in 12-712.

12-720 Water Resources Chemistry

This course provides a rigorous yet practical basis for applying the principles of physical chemistry to understanding the composition of natural waters and to the engineering of water and wastewater treatment processes. Topics covered include chemical equilibrium and kinetics; acid-base equilibria and buffering; solid precipitation and dissolution; oxidation and reduction reactions; adsorption on solids; and computer-aided problem solving. The primary objective of the course is to be able to formulate and solve chemical equilibrium models for complex aqueous systems. Knowledge of college-level general chemistry is assumed.

12-747 Special Topics: Sustainable Buildings

This course will cover the basics of the design, retrofit and monitoring of buildings to achieve energy efficiency. We will introduce energy simulation tools, the fundamentals of the most important building systems (i.e., heating, cooling, ventilation, insulation, etc.) and the technologies that can be used to monitor their performance.

12-765 Special Topics: International Climate Adaptation & Infrastructure Innovation

Although an international problem, climate change will affect each country's critical infrastructure in diverse ways. This course will focus on understanding how international communities are adapting and innovating to reduce critical infrastructure risk. Students will be able to list and describe natural hazards affected by climate change, focusing on their impacts on natural and built critical infrastructure systems in physically, socially, and economically diverse countries. Students will then use cost-benefit analysis, the triple bottom line approach (physical, social, economic), and robust decision making to analyze, compare, and contrast different countries' responses. The class will culminate in a final paper and presentation on one country's approach to decision-making under uncertainty for adaptation. Learning Objectives: By the end of the semester, you should be able to: · Understand risk. o Define risk, hazard, vulnerability, exposure, adaptation, hazard mitigation, greenhouse gas mitigation. Explain the link between some natural hazards and climate change o List 10 natural hazards and their impacts on the international community. · Analyze outcomes/impacts. o Predict how physically, socially, and economically detrimental a

given natural hazard will actually be in different critical infrastructure systems. o Compare and contrast different adaptations to reduce risk. · Create recommendations for improving adaptation in an international community.

Electrical & Computer Engineering

18-618 Smart Grids and Future Electric Energy Systems

The course offers an advanced presentation of modern electric power systems, starting from a brief review of their structure and their physical components, through modeling, analysis, computation, sensing and control concepts. Great care is taken to avoid presenting "practical" techniques built on dubious theoretical foundations and also to avoid building elaborate "mathematical" models whose physical validity and relevance may be questionable. Mastering both principles and relevant models is important for those who wish to seriously understand how today's electric power grids work and their challenging technical issues. This prepares students for working on applying many novel information processing concepts for designing and operating more reliable, secure, and efficient electric energy systems. Students interested in both applied physics and signals and systems should consider taking this subject. Once the fundamentals of today's power systems are understood, it becomes possible to consider the role of smart electric power grids in enabling evolution of future electric energy systems. Integration of intermittent energy resources into the existing grid by deploying distributed sensors and actuators at the key locations throughout the system (network, energy sources, consumers) and changes in today's Supervisory Control and Data Acquisition (SCADA) for better performance become well-posed problems of modeling, sensing and controlling complex dynamic systems. This opens opportunities to many innovations toward advanced sensing and actuation for enabling better physical performance. Modeling, sensing and control fundamentals for possible next generation SCADA in support of highly distributed operations and design are presented. Prior knowledge in 18-418 or 18-771 is highly recommended.

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18-743 Energy Aware Computing

This course provides a comprehensive coverage of topics related to energy aware and green computing. While it is widely recognized that power consumption has become the limiting factor in keeping up with increasing performance trends, static or point solutions for power reduction are beginning to reach their limits. This course is intended to provide an insight into: (i) power and energy consumption modeling and analysis; (ii) energy aware computing, i.e., how various power reduction techniques can be used and orchestrated such that the best performance can be achieved within a given power budget, or the best power efficiency can be obtained under prescribed performance constraints; and (iii) green computing in the context of large scale computing systems or smart grid-aware computing. Recommended: basic VLSI design, basic computer system organization, basic compiler design and OS knowledge. Prerequisites: Senior or Graduate Standing.

Engineering and Public Policy

19-638 Smart Grids and Future Electric Energy Systems

The course offers an advanced presentation of modern electric power systems, starting from a brief review of their structure and their physical components, through modeling, analysis, computation, sensing and control concepts. Great care is taken to avoid presenting "practical" techniques built on dubious theoretical foundations and also to avoid building elaborate "mathematical" models whose physical validity and relevance may be questionable. Mastering both principles and relevant models is important for those who wish to seriously understand how today's electric power grids work and their challenging technical issues. This prepares students for working on applying many novel information processing concepts for designing and operating more reliable, secure, and efficient electric energy systems. Students interested in both applied physics and signals and systems should consider taking this subject. Once the fundamentals of today's power systems are understood, it becomes possible to consider the role of smart electric power grids in enabling evolution of future electric energy systems. Integration of intermittent energy resources into the existing grid by deploying distributed sensors and actuators at the key locations throughout the system (network, energy sources, consumers) and changes in today's Supervisory Control and Data Acquisition (SCADA) for better performance become well-posed problems of modeling, sensing and controlling complex dynamic systems. This opens opportunities to many innovations toward advanced sensing and actuation for enabling better physical performance. Modeling, sensing and control fundamentals for possible next generation SCADA in support of highly distributed operations and design are presented. Prior knowledge in 18-418 or 18-771 is highly recommended.

19-655 Special Topics in Engineering and Public Policy

This course will provide a background in climate change science and its application to adaptation efforts. Students successfully completing this course will acquire a solid understanding of the climate system, how climate is expected to change regionally, and how societies can adapt. Central components of the climate system that will be studied include Earth heat budget, precipitation, the global circulation, and the mechanisms of weather. We will then survey global climate models, regional downscaling, and the process of detecting and attributing climate changes. This knowledge will be applied to explore regional climate impacts, including changes in droughts and floods, heat waves, hurricanes, Arctic climate change, and climate impacts on cities. For each type of climate change impact, adaptation efforts and barriers to adaptation will be discussed. Students will work on a team project to analyze selected regional climate adaptation efforts in more detail.

19-688 Innovation for Energy and the Environment

Issues in energy and the environment may be framed in different ways. Engineers may describe a technical system while social scientists may choose policy terms. To these views, this course adds the business and innovation dimensions, which provide additional motivation for change in these dynamic areas. The class will explore opportunities for economic, environmental and social value creation for several cases, each of which has its own set of considerations for resources, stakeholder perspectives, business challenges and technical opportunities. The course will emphasize utilization of methods, tools and frameworks to describe and evaluate potential innovation opportunities in the energy and environmental sectors. Upon completion of the course, students should be able to evaluate the economic and environmental aspects of business decisions in these sectors, and know how to assess possible adoption paths, impacts and benefits.

19-696 Special Topics: Sustainability and Innovation

This course will explore how technology and business contribute to sustainable development. Course segments will include examining global megatrends in ten major sectors (e.g., food, water, energy, health, etc.), opportunities and risks in these key sectors, and developing key metrics for success in sustainable development. Solution pathways that use existing, transferable, and new models in both policy and innovation will be discussed and proposed by the class. Issues for both large multi-nationals and start-ups will be covered. Class time will include a combination of lectures, guest speakers from industry, and problem solving activities. Students will experience how to create a business in this climate of sustainable development. Instructor is former CTO of Alcoa, and Co-Chair of the Vision 2050 project of the World Business Council for Sustainable Development. He is also currently an Advisor & Board Member at a number of Venture Capital firms and Adjunct Prof. at CMU. The course is intended for MS students. Upper-level undergraduates may enroll with permission.

19-710 Special Topics: Environmental regulation and Manmade Nanomaterial
Engineers and scientists developing new nanomaterial applications or evaluating nanotechnology risks need to be aware of the national and international regulatory framework they will work under. In this course students will develop an understanding of (1) relevant U.S. environmental law, its provisions and limitations for the regulation of nanotechnology, (2) current mechanisms for international governance of nanomaterials, (3) regulation (the rules for implementation of laws) and the process by which regulations are developed, particularly risk assessment, (4) the role of risk communication and public perception of risk in the regulatory process and risk management. This course will be built around reading assignments completed outside of class, discussion, and synthesis writing assignments. Course is open to graduate students; seniors may enroll with permission instructor.

19-717 Introduction to Sustainable Engineering
This course begins with an overview of the concept of sustainability, including changing attitudes and values toward technology and the environment through the twentieth century. Models for population growth, global food production, and global water resources are then presented, and current problems such as land use, urbanization, and energy and material resources are discussed. Models of industry based on life sciences are then explored, and tools for sustainable engineering are presented. These tools include metrics of sustainability, principles of design for the environment, methods for pollution prevention, and use of mass and energy balances in the design of sustainable systems.

19-883 Special Topics: Seminar in Climate and Energy Decision Making Under Uncertainty
In this seminar course, PhD students are given the opportunity to present their ongoing research in the area of climate and energy decision making under uncertainty and have feedback from their peers and from faculty. The goals of the course are to prepare CEDM PhD students to present their research work to different audiences, to understand how to communicate research results, and to build a collaborative and scientifically sound community of PhD students in the area of climate and energy decision making at Carnegie Mellon University. In some classes, instead of a PhD student presentation of his or her work, we may discuss instead key papers from the climate and energy decision-making literature. Open to doctoral students studying climate and energy issues or related areas.

English

76-719 Environmental Rhetoric
How people think and talk about the environment matters; it reveals what they value and shapes what they do. We will look at how competing discourses define man's relationship to the natural world, frame environmental problems, and argue for public action. As we compare the environmental rhetoric of naturalists, scientists, policy makers, and activists, we will trace an American history that has managed to combine mystical celebration with militant critique, and scientific research with public debate. Equally important, this course will prepare you to act as a rhetorical consultant and writer, studying how writers communicate the three "Rs" of environmental rhetoric: relationship with nature, the presence of risk, and the need for response.

Heinz College

90-768 Energy and the Environment
This course focuses on economics of regulation in the United States, with a focus on the regulation of energy and the environment. This class will start by using the framework of the history of oil and electricity regulation in the United States to analyze the theory of natural resource extraction, the formation and regulation of monopolies and cartels, and approaches to demand-side regulation. Then the class will explicitly turn to environmental regulation with readings on when regulation is necessary (and when it may not be). We will look at standard approaches to regulating point- and non-point-source pollutants including cap-and-trade, emissions taxes, Pigouvian taxes, and quantity controls like fuel economy standards. Finally, we will delve into some of the issues of regulation for renewable energy and technological advancement. The goal is for students to be able to understand the economic approach to analysis of energy and the environment, common critiques of this approach, specific types of solutions to environmental problems, and the advantages and disadvantages of these solutions.

90-779 The Shale Gas Revolution: Public Policy Challenges

This course will introduce a select group of students to the economic opportunities and regulatory challenges created by the unexpected and rapid emergence of abundant natural gas in regions of the United States like the state of Pennsylvania. It will also directly involve these students in an effort to inform public policy relating to shale gas production. Using a combination of readings, interdisciplinary lectures, and frequent guest lectures from experts, we will explore the shift in national and global energy systems created by the shale gas revolution (and to some extent, similar revolutions in oil production), the technology that has enabled it, the environmental risks and opportunities thereby created, and the various ways that shale gas production is regulated and taxed around the country, with a focus on Pennsylvania. This overview will enable students to analyze the current tax and regulatory policies governing the shale gas industry in Pennsylvania and make recommendations.

90-798 Environmental Policy and Planning

Environmental Policy and Planning provides an introduction to how environmental policies have been and can be designed/created implemented and evaluated amidst complex information-based social political and cultural processes. The course emphasizes a systems-based methodological approach for addressing the complexities involved in framing analyzing and designing an implementation plan for policy construction. The course also explores through landmark and contemporary case studies several dimensions of environmental policymaking: * Contextual historical and structural aspects of environmental policymaking at the local state federal and international levels * Use of quantitative and qualitative analytical tools (from the core program as well as new tools) * The process of how policies derive their meaning. Students in this course work on a final environmental policy project to demonstrate mastery of the knowledge and skill-based exercises explored during the term.

90-808 Energy Policy

This seminar will provide an introduction to modern U.S. energy policy. What lessons have we learned from past initiatives? How different is our current policy? How much influence does government really have? How does the U.S. interact with other countries? The class will begin with a discussion of the U.S. policy reaction to Arab oil embargoes of the 1970s — which resulted in the creation of the U.S. Energy Department and the first significant attempts to move the country from a dependence on (imported) oil. Besides describing the U.S. government components that play a role in the development and implementation of energy policy we will also analyze many of the relevant policy levers: economics technology politics public opinion and national security. The class will then turn to more recent developments - studying the development and implementation of energy legislation during the last decade. We will also focus on a few case studies — such as the Keystone Pipeline the Cape Wind Project and the development of the Marcellus Shale — that demonstrate conflicting viewpoints about appropriate energy policy. Finally we will conduct a crisis simulation in order to explore the national security implications of a global oil disruption. Each class will begin with a short discussion of current events in the energy sector. There will also be a number of guest lecturers including senior government officials.

90-821 Special Topics: Innovation for Energy and the Environment

Issues in energy and the environment may be framed in different ways. Engineers may describe a technical system while social scientists may choose policy terms. To these views, this course adds the business and innovation dimensions, which provide additional motivation for change in these dynamic areas. The class will explore opportunities for economic, environmental and social value creation for several cases, each of which has its own set of considerations for resources, stakeholder perspectives, business challenges and technical opportunities. The course will emphasize utilization of methods, tools and frameworks to describe and evaluate potential innovation opportunities in the energy and environmental sectors. Upon completion of the course, students should be able to evaluate the economic and environmental aspects of business decisions in these sectors, and know how to assess possible adoption paths, impacts and benefits.

90-828 Economics of Global Warming

The scientific community has concluded that human industrial activities are causing global temperatures to increase. Coping with the environmental, economic, and political consequences of this change is considered by many to be the preeminent public policy challenge of the 21st century. In this course, we will investigate the basic science of climate change and the prospective economic impact of global warming. We will also study the prospects and feasibility of the alternative energy and

transportation technologies available to us, drawing upon the deep reservoir of technological expertise available here at Carnegie Mellon. The heart of this course will be an in-depth analysis of the policy options the United States and the global community could adopt to mitigate the climate change challenge while still allowing for robust economic growth and development. We will investigate the economic costs of the various options and the way political realities are likely to shape and constrain policy at the national and international levels. Current and former officials at the state and national levels will offer an assessment of recent energy and climate change policy and the prospects for future policy change. The instructor, Professor Lee Branstetter, served as a Senior Economist at President Obama's Council of Economic Advisers in 2011-2012.

Mechanical Engineering

24-424 Energy and the Environment

Fuel cycles for conventional and non-conventional energy resources; relationships between environmental impacts and the conversion or utilization of energy; measures of system and process efficiency; detailed study and analysis of coal-based energy systems including conventional and advanced power generation, synthetic fuels production, and industrial processes; technological options for multi-media (air, water, land) pollution control; mathematical modeling of energy-environmental interactions and tradeoffs and their dependency on technical and policy parameters; methodologies for energy and environmental forecasting; applications to issues of current interest.

24-425 Combustion and Air Pollution Control

Formation and control of gaseous and particulate air pollutants in combustion systems. Basic principles of combustion, including thermochemical equilibrium, flame temperature, chemical kinetics, hydrocarbon chemistry, and flame structure. Formation of gaseous and particulate pollutants in combustion systems. Combustion modifications and post-combustion technologies for pollutant control. Relationship between technology and regional, national, and global air pollution control strategies. The internal combustion engine and coal-fired utility boiler are used as examples.

24-626 Special Topics in Air Quality

The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines.

24-629 Special Topics: Direct Solar and Energy Conversion

This course introduces graduates and senior undergraduates the principles and technologies for directly converting heat and solar light into electricity using solid-state devices. The first part of the course reviews the fundamentals of quantum mechanics, solid state physics and semiconductor device physics for understanding solid-state energy conversion. The second part discusses the underlying principles of thermoelectric energy conversion, thermionic energy conversion, and photovoltaics. Various solar thermal technologies will be reviewed, followed by an introduction to the principles of solar thermophotovoltaics and solar thermoelectrics. Spectral control techniques which are critical for solar thermal systems will also be discussed. By applying the basic energy conversion theory and principles covered in lectures, students will finish a set of 4 homework assignments. This course also requires one project in which students will work individually to review one present solar or thermal energy conversion technology.

24-642 Fuel Cell Systems

Fuel cells are devices that convert chemical potential energy directly into electrical energy. Existing fuel cell applications range from the small scale, such as portable cell phone chargers, to the large scale, such as MW-scale power plants. Depending on the application, fuel cell systems offer unique advantages and disadvantages compared with competing technologies. For vehicle applications, they offer efficiency and environmental advantages compared with traditional combustion engines. In the first half of the course, the focus is on understanding the thermodynamics and electrochemistry of the various types of fuel cells, such as calculating the open circuit voltage and the sources of voltage loss due to irreversible processes for the main fuel cells types: PEM/SOFC/MCFC. The design and operation of several real fuel cells are then compared against this theoretical background. The second half of the course focuses on the balance-of-plant requirements of fuel cell systems, such as heat exchangers, pumps, fuel processors, compressors, as well as focusing on capital cost estimating. Applying the material learned from the first and second halves of the class into a final project, students will complete an energy & economic analysis of a fuel cell system of their choice.

24-683 Design for Manufacture and the Environment

Design for Manufacturing and the Environment examines influences of manufacturing and other traditionally downstream issues on the overall design process. Manufacturing is one facet that will be examined. Other downstream influences that will be studied include: assembly, robustness and quality, platform design, maintenance and safety, economics and costing, lean manufacturing and globalization. In addition, a core part of the course will focus on environment-based design issues. The class will study basic fundamentals in each of these areas and how they affect design decisions. Prerequisites: Senior standing in mechanical engineering, or permission of instructor

24-722 Energy System Modeling

This course focuses on the thermodynamic modeling of energy systems with emphasis on energy/availability analysis techniques. These techniques are developed and applied to both established and emerging energy technologies, such as internal combustion engines, gas- and coal-fired power plants, solar and wind energy systems, thermochemical hydrogen production cycles, and fuel cells. The course will also consider the integration of components such as reformers and electrolyzers. Modern computational tools are used throughout the course. The course culminates with a group project that requires developing sophisticated, quantitative models of an integrated energy system. Students are expected to have completed an undergraduate course in thermodynamics comparable to 24-221.

Undergraduate Courses Spring 2013

Architecture

48-205 Architecture Design Studio: Materials

Building on the fall studio, the spring semester is concerned with more in-depth understanding and development of designs for small-scale buildings, now informed by greater knowledge related to materials, fabrication, and the act of construction. Following the "New Materiality" evident in architecture today, and acknowledging the importance of materials and assembly techniques for sustainable design, we seek to explore the aesthetic and experiential meaning of materials (WHY?), and the technical knowledge related to the use of materials and the processes of construction (HOW?). The creative opportunities and design implications of using varied materials, structural systems, fabrication and assembly techniques—both analogue and digital—are elaborated, especially as they determine the artistic, conceptual, poetic, creative, spatial, and experiential aspects of architecture. The studio projects, lectures, and the required building study will focus on the application and integration of knowledge acquired in a parallel "Materials & Assembly" course.

48-405 Architecture Design Studio: Systems Integration
In today's climate of complex clients and large-scale architecture, design students research and discuss broad political, economic, infrastructure, management and operational systems. Following this theme and in the students' quest of building integration, they examine the complex interrelationships between performance criteria, building subsystems and their integration, specification, and evaluation. This studio is concerned with the detailed design development relating to the spatial, visual, acoustic and thermal performance of complex buildings as well as the long-term integrity of the integrated systems. Students achieve design integration of at least two building systems and their interdisciplinary objectives -structure, enclosure, interior, mechanical, communications and information, and the safety systems—addressing issues of constructability and technical innovation while combined with suitability to the user, studied in the previous semester of Occupancy.

48-420 City as Landscape: Geography as Method and Metaphor
This design theory seminar will explore the emergence of landscape, ecology, and infrastructure as new conceptual, aesthetic and methodological organizers for architectural and urban form. Over the first decade of the twenty-first century it has become clear that the form of urban settlement is driven by complex interacting systems, ecologies and economies resulting in a physical form that has surpassed our traditional notions of "city" or "landscape," while producing highly unsustainable patterns of development with both ecological and cultural impacts. At the same time contemporary culture has evolved into a hyper-mediated, networked and globalized state which appears increasing unstable, creating both positive negative potentials. During this period the design professions have successfully integrated sustainability at the scale of buildings and products, however, the question of how to best do this at the urban scale remains open for debate. For those working at the scale of the city, one of the most promising recent attempts to reformulate design has been the conceptual merging of landscape and urbanism in to a hybrid practice of landscape, infrastructural or ecological urbanism. Many have argued that landscape architecture, with its emphasis on processes, surfaces, frameworks and ecologies, is better suited to understanding and intervening in the contemporary urban condition. At the same time, much contemporary architecture has explored notions of surface, performance and flexibility, exploring the idea of building as landscape. Both of these approaches have drawn on analytical tools from sources such as geography and ecology to understand spatial and cultural flows.

48-596 LEED Buildings and Green Design
Green building and sustainable design have been rapidly gaining acceptance in all sectors of the building market. Global issues of energy use, emissions, resource depletion, and land use are forcing building professionals to re-evaluate standard design and construction processes, and look to more environmentally friendly practices. The U.S. Green Building Council (USGBC) developed green building rating systems entitled Leadership in Energy and Environmental Design (LEEDTM) in order to define "green building" by establishing a common standard of measurement. LEED considers green building methods and technologies in several categories including site, water, energy, materials, and indoor air quality, and awards points towards an overall green building rating of certified, silver, gold or platinum. Currently, LEED registered projects make up 3% of the current U.S. commercial building market, and Pennsylvania is the third leading state with LEED registered projects. There is now a demand for design professionals with knowledge and experience not only in sustainable design but specifically with the LEED rating system as well. This course will provide students with background knowledge of the USGBC, the LEED system, as well as referenced standards related to specific topics. The course will benefit greatly from the large number of LEED projects in the Pittsburgh region, which will serve as case studies. Upon completion of the course, students will be prepared to take the LEED Professional Accreditation Exam, which is quickly becoming the standard of recognition for green building professionals.

Business Administration

70-332 Business, Society and Ethics
The course draws upon actual cases to explore fundamental questions faced by businesses operating in the United States and elsewhere in the world. What justifies governmental regulation of your business? What are the rights of employers and employees? How does the law protect consumers? What laws protect the environment? How do you choose the best legal form for your business? What are the lines of power within a corporation? What protections are available to shareholders? How do the antitrust laws protect competition? What responsibilities does a business have to the community in which it operates? What is the ethical foundation on which business ought to be conducted? The course puts businesses in their legal and ethical context.

CIT Interdisciplinary Courses

39-399 Special Topics: Land Revitalization in the New Global Economy
In this seminar course, we will explore the US process for land revitalization and compare it to the causes and remedies found in China. The results will provide context for a better understanding of global land management challenges that require a balance between the culture, the economy and the environment. The centerpiece of the course is a spring break, 9-day trip to China, visiting the cities of Hong Kong, Shenzhen and Guangzhou, while hearing from local academics and practitioners that are working on land revitalization projects. Students will participate in pre- and post- trip lectures (with some required reading) and will submit a final paper summarizing the regulatory and cultural differences between the US brownfield development process and the sites visited in China. There are no prerequisites. The course is open to juniors, seniors and graduate students and is most pertinent to students in civil and environmental engineering, public policy, architecture, and land use planning.

Civil & Environmental Engineering

12-351 Environmental Engineering
Provides a scientific and engineering basis for understanding environmental issues and problems. Introduces material and energy balances for tracking substances in the atmosphere, source and ground waters, and soil systems. Pertinent environmental laws are described, simple quantitative engineering models are developed, and qualitative descriptions of environmental engineering control technologies are presented.

12-636 Geotechnical Engineering
Behavior of geotechnical structures; engineering design of geotechnical structures considering failure modes; uncertainties; economic issues, required design formats and relevant code provisions; performance requirements for foundations, subsurface investigations; allowable stress and LRFD design approaches; reliability-based design; shallow foundations; deep foundations; retaining structures; reinforced concrete foundations.

Design

51-274 Design and Social Change
In this course we will examine the important relationships of history, culture, policies and the environment in communication design and industrial design. Conversely we will study the ways in which design can affect our culture and environment, both positively and negatively. Topics include: sustainability, universal design, system thinking and system visualization.
While various cultures will be acknowledged and discussed, the major emphasis will be on Western culture. Through lectures, videos, reading and projects, students will develop their ability to incorporate historical context and consideration of potential consequences into their design process.

Engineering and Public Policy

19-101 Introduction to Engineering and Public Policy
This course examines the processes of public and private decision making and of policy formation, which shape the evolution of a technology and its impact on our society. Technology plays an important role in shaping our worlds. At the same time, social forces often play a central role in the evolution of a technology. A particular technology such as an automobile or computer is chosen to study technology and policy in context. Specific topics covered in the case of the automobile includes automotive design and manufacture, safety, pollution, fuel economy and their interactions. In each area, we discuss the technological and institutional issues, their interaction, the possible need for public policy and the factors that govern the policy. The course will involve several group problem-solving sessions.

History

79-359 Sustainable Innovations: Ideas, Policies & Technologies to Make a Better Planet
Life on the big ball is not at all what it used to be, nor at all what it will be. The instability and deterioration of past societies that resulted from miscomprehending and misusing natural and human resources will be briefly surveyed. Throughout most of the semester, we will discuss the origins, implementation, effects, and prospects of intellectual, regulatory, and technological inventions for greening the blue marble. We will read widely in fields useful for navigating Spaceship Earth – agricultural science, earth and planetary sciences, ecology, economics, engineering, environmental law, and regional planning, among others. This course is open to all students.

79-372 Perspectives on the Urban Environment
This course will explore the interaction of cities, technology and the natural environment over time. In doing so it will consider major issues confronting cities today including landscape and site changes; water supply, wastewater disposal and flooding; solid waste disposal; transportation and suburbanization; energy changes; and the impact of deindustrialization.
These themes will be approached through a combination of class discussions, lectures, and visiting speakers. Class participation is expected, and will comprise a portion of the grade. In addition to required texts, readings will be distributed on Blackboard.

Philosophy

80-244 Environmental Ethics
The aim of the course is to provide students with an introduction to environmental ethics. One aspect of environmental ethics is the study of values underlying human relations to the natural environment. In particular, we are interested in issues that arise when these values conflict. This course begins with a discussion of our current environmental crises, and different approaches to solving these crises. Many of these solutions, however, depend on particular kinds of knowledge, particularly scientific knowledge, about our environment. Thus, another important aspect of environmental ethics is determining what we do, and what we can, know. To address these issues, we will explore some problems in philosophy of science, with special emphasis on the various eco-sciences.

80-344 Management, Environment, and Ethics
This course examines and poses answers to the following question: "What are the legitimate environmental responsibilities of organizational managers from the private, public and nonprofit sectors and how can they be best fulfilled?" This query will provide the course with its major theme and framework. But in order to do justice to it, three interrelated areas that are presupposed by this question will need to be explored first. These areas are: 1) applied ethics, 2) management ethics and 3) environmental ethics. The first half of the course will concentrate upon these three areas. The second half of the course will focus upon management and the environment employing the insights gained during the first half. Here students will review and evaluate past and current management practices with respect to the environment, organizational policies dealing with the environment and the role of government in the process of determining environmental responsibilities in management. Environmental concerns on the international level and their impact upon organizational management, the emergence of the "environmental affairs manager" within organizations, balancing environmental responsibilities with other management responsibilities and examples of management responses to the environmental crises will also be examined during this portion of the course.

Social and Decision Sciences

88-412 Economics of Global Warming
The scientific community has concluded that human industrial activities are causing global temperatures to increase. Coping with the environmental, economic, and political consequences of this change is considered by many to be the preeminent public policy challenge of the 21st century. In this course, we will investigate the basic science of climate change, the

prospective economic impact of global warming, the uncertainty involved in long-run climate forecasting, and the technological alternatives available to us as we seek to mitigate the impact of human industrial activity on global warming. The heart of this course will be an in-depth analysis of the policy options available to the United States and the global community. We will investigate the economic costs of these options and the way political realities are likely to shape and constrain policy at the national and international levels.

Carnegie Mellon University - Campus Wide Studies

99-234 Environment Today: The Three E's of Water; Policy, Strategy, and Uncertainty
The goal of this course is to bring together students, across every academic discipline, over a weekend to discuss environmental issues affecting our planet. This spring semester, Environment Today focused on the "Three E's" of one of our most essential resources: Water. Each day of the course featured speakers, panelists, or service focused activities on not only the environmental impact affecting our water resources, but also other issues such as social equity and community engagement in regards to water restoration projects, green design and traditional sustainability concepts in regards to water quality and quantity issues, and the policy and economics of water as a resource.

Graduate Courses Spring 2013

Architecture

48-723 Performance of Advanced Building Systems
Advanced Building Systems Integration This is a graduate level course that focuses on commercial building performance achieved through systems integration. In lectures, class discussion, and student projects, we will explore the topic of building performance, the design and technical strategies that support sustainable high performance; the design, construction and operation processes that are likely to produce sustainable high(er) performance buildings; and the current state of theory versus practice. The course assumes a basic understanding of buildings' impact on the environment, of building design and materials performance, and the calculation of building heating and cooling loads. On that foundation, we will examine the concept of systems integration and how this approach can sustain the occupants and the environment far better than conventional design, construction and operation. Although US climate, building conventions and codes will be our reference point, we will broaden our discussion by using examples and data from many other countries. An essential aspect of our exploration will be identifying successful built projects and examining the factors that may have allowed those projects to succeed. If this course meets its objectives, students who successfully complete the material will understand and be able to discuss sustainable building performance characteristics, will understand the systems integration approach and how it differs from conventional approaches to building design, and will know how to positively affect architectural and engineering decisions to support the design, construction and operation of sustainable high performance buildings.

48-729 Productivity, Health and the Quality of Buildings
Given the growing demand for green buildings by federal and private sector clients, professional practices are tooling up all over the world to deliver high performance, environmentally responsive, green buildings and communities. However, investments in green, high performance building solutions and technologies are still limited by first cost decision-making, and life cycle tools are still largely inaccessible to professionals. A building investment decision support tool BIDS- continues to be developed by the Center for Building Performance and Diagnostics at Carnegie Mellon University, with the support of the Advanced Building Systems Integration Consortium. This cost-benefit decision support tool presents the substantial cost-benefits of a range of advanced and innovative building systems designed to deliver privacy and interaction, air quality, ergonomics, lighting control, thermal control, network flexibility, and access to the natural environment - from field case studies, laboratory studies, simulation studies, and other research efforts. This course will explore the relationship of quality buildings, building systems, and land-use to productivity, health, well-being and the environment. The course will engage students in the literature that relates building design decisions to ten cost/performance impacts: energy, facilities

management, organizational change, technological change, attraction/retention (quality of life) of employees, individual productivity, organizational productivity, salvage/ waste, tax/ insurance/ litigation, and health.

48-795 LEED, Green Design and Building Rating in Global Context

LEED, Green Design and Building Rating in Global Context is a graduate level mini-course that examines holistic, integrated strategies for sustainable building design, construction and operation. The course is organized within the framework of the US Green Building Council's Leadership in Energy and Environmental Design (LEED) Rating System: location, site, water, energy, materials, and the interior environment. Within that framework, we explore strategies promoted within LEED and compare/contrast them with strategies in the rating systems of other countries. We also consider additional ways to encourage development of better buildings, e.g., codes and standards, incentives, and project delivery methods. The course focuses on the concepts underlying rating system credits, the national contexts that can produce different rating systems, and substantive improvement in building performance. This course provides the foundation for taking USGBC's LEED Green Associate exam. More importantly, students who successfully complete the course will understand buildings powerful impact on the environment and equally powerful strategies to address those impacts. There are no prerequisites for this course. However, because the course moves quickly and we are discussing improvements to building practice, a basic knowledge of the vocabulary, design, construction and operation of buildings is assumed.

Chemistry

09-710 Introduction to Green Chemistry

Students will learn about green chemistry as the design of chemical products and processes that reduce and eliminate the use and generation of hazardous substances. The key role that sustainability ethics can play in redirecting the chemical enterprise toward sustainable technologies will be highlighted. With elemental toxicants such as lead, the industrial history (including the ancient history), chemical properties, mechanistic toxicity, and progress with reduction and elimination will be analyzed to develop understanding on the criticality of avoiding the like in the future. Particular attention will also be paid to persistent, bio accumulative, molecular toxicants that are responsible for major adverse effects on human health and the environment—the material will cover the developmental history, uses and perceived benefits, mechanisms of toxicity, and extraordinary cultural struggles that have accompanied attempts to balance economic pluses against health and environmental negatives. The findings of environmental health scientists relating to low dose adverse effects of certain everyday chemicals will be examined. This will include an analysis of non-monotonic dose-response behaviors that have their roots in the disruption of the endocrine system's control over cellular development. A significant effort has been made by the instructor to produce a course that is suitable for students from multiple disciplines. The overarching goal is to develop critical thinking on sustainability related technical topics. Graded materials are associated mostly with essay assignments based on student analyses of books in sustainability ethics, low-dose toxicity discoveries, and industrial history that reveals the underlying dynamics of the chemical enterprise that are either pluses or minuses for sustainability. This course is recommended for students in the junior and senior year.

Civil & Environmental Engineering

12-604 Transportation Engineering

Introduction to traffic engineering and highway design providing practical experience that can be used directly in the workforce. Course material will provide a solid foundation in preparing for the Professional Engineer exam. The course incorporates the "soft" side of transportation engineering with tasks such as traffic analyses and traffic studies and the "hard" side of transportation engineering including traffic signal design, signing design, pavement marking design, maintenance and protection of traffic during construction design, and highway design.

12-648 CEE Senior Research Project
This course is designed to give students the opportunity to work on an open-ended project under the direction of a faculty member in the Civil & Environmental Engineering department. To register for this course, a student must have the approval of the faculty member for both the research topic and the number of units. A student in this course must write a proposal and submit progress reports to the advisor. The student must also make a formal presentation of the project results and submit a final report to the department. Senior standing in CEE and permission of the project advisor.

12-651 Air Quality Engineering
The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines.

12-657 Water Resources Engineering
Principles and applications of open channel flow. Hydrology of surface and ground water sources and the estimation of water requirements. Planning and design of water distribution and wastewater and storm water collection systems. This course is offered every other spring semester.

12-714 Environmental Life Cycle Assessment
Cradle-to-grave analysis of new products, processes and policies is important to avoid undue environmental harm and achieve extended product responsibility. This course provides an overview of approaches and methods for life cycle assessment and for green design of typical products and processes using the ISO 14040 family of standards. This includes goal and scoping definition, inventory analysis, life cycle impact assessment (LCIA), interpretation, and guidance for decision support. Process-based analysis models, input-output and hybrid approaches are presented for life cycle assessment. Example software such as MATLAB, Excel, and Simapro are introduced and used in assignments. A group life cycle assessment project consistent with the principles and tools of sustainability to solve real-world engineering problems is required.

12-718 Sustainable Engineering Project
This course integrates and exercises students in a significant sustainable engineering and/or environmental project that is team-based and built upon the knowledge, skills, and technologies learned in the core and specialist courses in the EESS graduate curriculum.

Heinz College

90-789 Sustainable Community Development
This course will involve in-depth examination of the economic and social value that is created when development occurs in a sustainable manner. The various components of comprehensive community development will be defined through class lectures, guest speakers, and case studies. These components will include: housing, business and economic development, cultural and social development, transportation systems, and open spaces. Economic and design comparisons will be drawn between sustainable and non-sustainable models of development. The course will also consider how public policy and private decision-making can be influenced by well-organized community planning and advocacy efforts.

90-733 Urban Development
This course is an overview of the urban development process in cities across the United States. The process is controlled by a wide range of players including developers, public sector elected and appointed officials, architects, lenders, planners and community organizations. Developers can range from private for profit development corporations to nonprofit institutions and community development corporations. All have specific and sometimes conflicting goals for the development of the environment. The course will review the roles and responsibilities of each. Overlaid on these is the role of federal, state and local government in the development process. Government policy influences many different aspects of the development process ranging from project design and zoning issues to transportation requirements. Government policy also provides critical funding in the way of government subsidies and tax incentives. However, with the major reduction of government funding on all levels in recent years, especially the federal government, it has become incumbent on developers working with local governments to raise capital from other sources in order to fund development projects. The course will also focus on the raising capital through the public debt markets and develop an understanding of government revenues generated from taxes and fees that are utilized to pay principal and interest on the debt issued to subsidize urban development projects.

90-734 Urban Policy
This course will examine policies and forces that have shaped our modern urban form. We will set our analysis in the context of a review of the historic development of cities. After an overview of early history, we will concentrate on late 19th and 20th century city development. We will examine the series of post war government and private sector policies that supported anti urban trends that led to current urban patterns. The course will conclude with a discussion of policies and remedies that can support sustainable urban growth.
The course will concentrate on the physical, geographical and built aspects of cities -- the "public realm", the spaces we all share -- but it will also address the relation between the physical nature of cities and the quality of community that develops.

90-754 Engineering Public Policy Change Seminar
Policy analysts, non-profit administrators and other professionals are constantly envisioning changes in public policy that they believe will improve the public good. But frequently for their ideas to become realities, public legislation is necessary. Enter politics, political process and politicians. Indeed, elected politicians are the ultimate decision-makers in changing public law. The political process can be very messy, but students can develop an understanding of how to develop and execute a multi-year strategy to engineer the legal enactment of significant public policy change. An engineer is "somebody who plans, oversees, or brings about something, especially something that is achieved with ingenuity..."

90-758 Ethics & Public Policy in a Global Society
The first section of the mini-course will be devoted to a discussion of the nature of ethics and applied ethics. Here a framework useful in the ethical analysis of issues, problems and dilemmas in public life will be constructed. The second section of the course will demonstrate the usefulness of this framework in the analysis and evaluation of policy issues from a normative point of view. In this section, various arguments concerning the nature of the social ethics that form the background of policy debates also will be a focus in the mini-course. The course will consider: reproductive rights matters, end-of-life decisions, questions about free speech, social and economic justice and environmental considerations.

90-765 Cities, Technology and the Environment
This course will explore the interaction of cities, technology and the natural environment over time. More specifically, it will consider the evolution of several major issues confronting cities today: (1) water supply, wastewater disposal and flooding; (2) Energy and Environment; (3) Transportation, suburbanization and land use; and (4) Brownfield creation and development. In a number of instances, the Pittsburgh region will be used to provide examples of these issues. These themes will be approached through a combination of class discussions, lectures, and visiting speakers.

90-827 Economics of Development
The purpose of this course is to build an understanding of key economic problems that face developing countries. In the first part we will focus on general models of growth and development. This will include a look at growth theory, structural models of development and more recent innovations in thinking about growth. In the second part of the course we will concentrate on specific, mostly domestic problems of economic development. These challenges include poverty and income inequality, agricultural and rural development, the role of human capital, credit and finance, and health and nutrition. The final section of the course will deal with the challenges faced by developing countries in an increasingly global context. This will include issues

of trade, macroeconomics and international finance. The course will mix theory with empirical analysis. In addition to traditional economic analysis of development problems, we will also spend time examining insights from two more recent perspectives – institutional economics and the methodological approaches of randomized controlled trials (so-called "field experiments). We will also include brief case studies as a means of testing our analytic knowledge against the complexity of reality.

Carnegie Mellon University-Campus Wide Studies

99-234 Environment Today: The Three E's of Water; Policy, Strategy, and Uncertainty

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