# Master in Environmental Building Design

The Department of Architecture in the School of Design at the University of Pennsylvania offers an advanced, one-year Master in Environmental Building Design (MEBD) for architects seeking new skills and competitive advantage in the growing field of sustainable design.

With the renewed urgency of environmental issues—from global climate change to resource shortages and “net-zero” design—architects are faced with demands for new kinds of services that require a new kind of professional. LEED accreditation is only a start, helping designers utilize existing technologies, but a wider range of skills is required to achieve real innovation and to meet the needs of clients in this rapidly changing field. New building design, renovation of existing buildings, and environmental analysis at many scales are critical aspects of comprehensive environmental design. The challenge to architects is to operate at scales greater and smaller than that of the building, requiring the understanding of the chemistry of materials as well as consideration of the impact of whole populations of buildings on their local, regional, and global ecosystems.

The Master in Environmental Building Design is a specialized, post-professional degree developed to train architects in the new skills and knowledge required for environmental design and especially in the design techniques with which those skills must be integrated into the practice of architecture. The one-year course of study includes coursework on building performance simulation, integrated building design, building envelopes and systems, lighting, daylighting, and the theory and practice of environmental design. Coursework is complemented and extended by a Performance Design Workshop and then explored in depth in an intensive Environmental Design Studio in the early summer.

The Department of Architecture at Penn has gathered a remarkable team of experts to teach in the new program. The MEBD will operate in close coordination with the Penn-Tsinghua T.C. Chan Center for Building Simulation and Energy Studies, drawing on the expertise of faculty engaged in research at the center and providing case studies and research projects for students in the MEBD. The new program also builds on the certificate program in Ecological Architecture, currently available to students in the Master of Architecture program, though it significantly increases the focus and intensity to advance architects’ skills in this crucial area of design and technology.

Director: Dr. William W. Braham, FAIA

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## Curriculum

The MEBD curriculum has four required courses, a selection of designated electives, some optional, open electives, and a design laboratory. The structure of the curriculum is outlined in the chart below.

The sequence of required courses develops from broad principles and simulation skills in the Fall semester to integration of those skills in the Spring semester, culminating in the design laboratory in the Summer session. Designated electives support the required sequence with more detailed explorations of environmental technologies at different scales, from building components to urban development. Optional electives allow students to explore courses outside of the program that extend or complement their studies.

| MEBD Curriculum | | | |
|---|---|---|---|
| Fall | ARCH 751 | Ecology, Technology and Design | 1 |
| | ARCH 753 | Building Performance Simulation | 1 |
| | ARCH xxx | Designated Elective | 1 |
| | ARCH xxx | Designated Elective | 1 |
| | ARCH xxx | Elective (optional) | |
| Spring | ARCH 752 | Integrated Building Design | 1 |
| | ARCH 754 | Performance Design Workshop | 1 |
| | ARCH xxx | Designated Elective | 1 |
| | ARCH xxx | Designated Elective | 1 |
| | ARCH xxx | Elective (optional) | |
| Summer | ARCH 708 | Environmental Design Studio | 2 |
| | | Total Course Units | 10 |

## Course Listing

The specific courses available in the program this academic year are listed in the following pages, and are adjusted each year. The pre-requisite courses that are listed do not count towards the degree, but are included as a scheduling convenience for those students who decided to sit in on them for a review. Students may also substitute an approved Independent Study Course (Arch 999) for the Designated Electives or Optional Electives. These are arranged directly with individual instructors and can allow students to explore individual research interests.

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Course Roster: **Master of Environmental Building Design (MEBD)**

| Course No. | Course Title | Co-Req | Day-Time | Instructor | Location | CUs |
|---|---|---|---|---|---|---|
| **Fall 2011** | | | | | | |
| **Pre-Requisites** | | | | | | |
| **ARCH 533 401** | Environmental Systems I | | T12-1:30 | Martin | MEYH B3 | 0.5 |
| **Required Courses** | | | | | | |
| **ARCH 751 001** | Ecology, Technology, and Design | | R12-3 | Braham | MEYH B13 | 1 |
| **ARCH 753 001** | Building Performance Simulation | | M9-12 | Yi | MEYH 321 | 1 |
| **Designated Electives** | | | | | | |
| **ARCH 631 001** | Technology Case Studies I | | T3-6 | Falck | MEYH B3 | 1 |
| **ARCH 757 001** | Buildings and Behavior: Bringing the IGCC to | | T9-12 | Hughes/Billhymer | MEYH B6 | 1 |
| **CPLN 531 001** | Introduction to Environmental Planning & Policy | | TR 1:30-3 | Daniels | | 1 |
| **EAS 501 401** | Energy & its Impacts | | TR 6-7:30 | Lior | | 1 |
| **EAS 503 401** | Energy Systems & Policy | | W5-8 | Huemmler | | 1 |
| **EAS 505 401** | Climate Policy & Tech | | TR 4:30-6 | Huemmler | | 1 |
| **ENVS 494 660** | Toward Environmental Sustainability On Penn's | | W5:30-8 | Garofalo | | 1 |
| **HSPV 516 001** | Building Diagnostics | | F2-5 | Henry | | 1 |
| **Spring 2012** | | | | | | |
| **Pre-Requisites** | | | | | | |
| **ARCH 534 401** | Environmental Systems II | | T12-1:30 | Braham | MEYH B3 | 0.5 |
| **Required Courses** | | | | | | |
| **ARCH 752 001** | Integrated Building Design | | M9-12 | Malkawi | MEYH B5 + C:321 | 1 |
| **ARCH 754 001** | Performance Design Workshop | | W9-12 | Yi | MEYH 321 -wait | 1 |
| **Designated Electives** | | | | | | |
| **ARCH 632 002** | Performance and Design: Parametric Integration | | R9-12 | Yi | MEYH 321 | 1 |
| **ARCH 632 004** | Integrated Design for High Performance | | R9-12 | Martin/Diemer | FURN 306 - | 1 |
| **ARCH 632 005** | Daylighting | | F9-12 | Phinyawatana | MEYH B5 9 | 1 |
| **ARCH 632 006** | Daylighting | | F1-4 | Phinyawatana | MEYH B5 1-2:30; | 1 |
| **ARCH 638 004** | Six Facts, Six Scales (1st half) | | T6-9 | Faircloth | MEYH B5 | 0.5 |
| **ARCH 638 007** | Building Envelopes (2nd half) | | T3-6 | Sonntag | FURN 306 | 0.5 |
| **ARCH 712 401** | Cultural Ecology | ARCH 712 402 | T10:30-12 | Leatherbarrow/Wesley | FURN 306 | 1 |
| **ARCH 712 402** | Recitation: Cultural Ecology | ARCH 712-401 | F11-12 | Caicco | MEYH B3 | 0 |
| **ARCH 734 001** | Architecture & Ecology | | T9-12 | Martin | STIT B30 | 1 |
| **CPLN 641 001** | Progressive Development | | R9-12 | Landis | | 1 |

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| Course No. | Course Title | Co-Req | Day-Time | Instructor | Location | CUs |
|---|---|---|---|---|---|---|
| **EAS 502 401** | Renewable Energy & its Impacts | | T6-7:30 R | Lior | | 1 |
| **HSPV 551 001** | Building Pathology | | F2-5 | Henry | | 1 |
| **LARP 760 001** | Topics in Ecological Design: Reclamation of | | F10-1 | Young | | 1 |
| **LARP 760 002** | Topics in Ecological Design: Green Roof | | F2-5 | Weiler | | 1 |
| **LARP 760 003** | Topics in Ecological Design: Ecological | | F2-5 | Hopkins | | 1 |
| **LGST 815 401** | Environmental Management Law & Policy | | W3-6 | Orts | | 1 |

## Summer 2012

### Required Courses

| | | | | | | |
|---|---|---|---|---|---|---|
| **ARCH 708 910** | Environmental Design Laboratory (5/23-7/1) | | MTWRF 12-6 | Faculty | | 2 |

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## Fall 2011 Course Descriptions

| Course No. | Course Title | Co-Req | Instructor | CUs |
|---|---|---|---|---|

## Graduate

**ARCH 533 401** Environmental Systems I — Malkawi — 0.5

An introduction to the influence of thermal and luminous phenomenon in the history and practice of architecture. Issues of climate, health and environmental sustainability are explored as they relate to architecture in its natural context. The classes include lectures, site visits and field exploration.

**ARCH 534 401** Environmental Systems II — Braham — 0.5

This course examines the environmental technologies of larger buildings, including heating, ventilating, air conditioning, lighting, and acoustics. Modern buildings are characterized by the use of such complex systems that not only have their own characteristics, but interact dynamically with one another and with the building skin and occupants. Questions about building size, shape, and construction become much more complex with the introduction of sophisticated feedback and control systems that radically alter their environmental behavior and resource consumption. Class meetings are divided between lectures, demonstrations, and site visits. Course work includes in-class exercises, homework assignments, and a comprehensive environmental assessment of a room in a building on campus.

**ARCH 631 001** Technology Case Studies I — Falck — 1

A study of the active integration of various building systems in exemplary architectural projects. To deepen students' understanding of the process of building, the course compares the process of design and construction in buildings of similar type. The course brings forward the nature of the relationship between architectural design and engineering systems, and highlights the crucial communication skills required by both the architect and the engineer.

**ARCH 632 002** Performance and Design: Parametric Integration — Yi — 1

This course develops techniques for integrating environmental performance analysis and the design of buildings, with an emphasis on parametric methods. Performance analysis techniques can provide enormous amounts of information to support the design process, acting as feedback mechanisms for improved performance, but careful interpretation and implementation are required to achieve better buildings. Parametric descriptions will be combined with decision-making methods to achieve more complete integration.
Students will begin by using analytical tools to examine the environmental performance of existing buildings. Following the results of the analysis, the students will develop high-performance goals and use analytical tools to develop an initial design proposal. Different decision-making and parametric form control methods will then be introduced to achieve high performance designs.

**ARCH 632 003** Constructing Technologies Integrating Matter + — Trubiano — 1

This seminar/workshop is dedicated to the promotion of architectural innovation in the field of construction technology. Students will design and fabricate building related prototypes that productively respond to a well documented and socially relevant environmental need. Matter + Energy are the two fields of enquiry which will guide and structure both the research seminars and the design/build workshop; their articulated integration the goal of each prototype. Materials such as composites and plastic/polymers will be central to the investigation, as will the energy related topics of thermodynamics, light/heat studies and solar technology. Invited design and building industry professionals will advise student teams and offer critical reviews of their process throughout the semester. Lastly, students will be introduced to design metrics used to evaluate the environmental impact of their material and energy choices, be they embodied energy calculations, carbon emissions, or Life Cycle Assessments.

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## Spring 2012 Course Descriptions

| Course No. | Course Title | Co-Req | Instructor | CUs |
|---|---|---|---|---|
| **ARCH 632 004** | Six Facts, Six Scales (3/14-4/26/11) | | Faircloth | 0.5 |

From the perspective of the research driven practice of KieranTimberlake, Research Director Billie Faircloth will lead the seminar through the dissection of six numerical facts at six numerical scales. Numerical facts, originating from disciplines such as industrial ecology, environmental management, materials engineering, biology, and neurology, will be understood through the pairing of theoretical and technical reading. Seminar participants will define each scaled fact's potential participation as a parameter in the generation of innovative design solutions for the built environment.

**ARCH 632 005** Daylighting — Phinyawatana — 1

This course introduces fundamental daylighting concepts through lectures and tools for analyzing daylighting design through design workshops. The central objective of the course is to provide students with both the fundamental knowledge and tools to analyze the effectiveness of design options. Fundamentals of daylighting availability and visual perception are introduced, and then advanced design-oriented techniques are developed in workshops and a final project.

**ARCH 632 007** Building Envelopes (3/14-4/26/11) — Sonntag — 0.5

**ARCH 638 005** Lighting (1/12-3/4-11) — Bernecker — 0.5

The course examines the fundamentals of lighting and perception, the different types and sources of artificial lighting, their interaction with materials, and advanced techniques of luminous design and analysis. The balance between design and energy efficiency is studied directly. Class work involves lectures, in-class exercises, and a final project. *NOTE*: Classes meet the 1st half of the semester, January 12 - March 5, 2010.

**ARCH 708 910** Environmental Design Laboratory (5/23-7/1) — Trubiano — 2

An intensive, 6 week design laboratory. The lab will build on the simulation and analysis techniques developed in the sequence of required course and electives to fully develop performance based design of building projects. The location of the lab may be at Penn or abroad.

**ARCH 712 401** Cultural Ecology — ARCH 712 402 — Leatherbarrow — 1

This course will study and argue a single thesis: that the architects of the early 20th century did not neglect the environmental and cultural context of their buildings because they were narrowly focused on the production of free-standing and radically new objects of design, but developed green buildings that combined attention to environmental issues with both imaginative approaches to social and cultural purposes, and a new understanding of aesthetic content. A review of contemporary ecological mandates will begin the course. In depth studies of specific buildings will follow, looking again at works we assume we know perfectly well. The course will end with a return to contemporary conditions. With a more nuanced view of our inheritance we will ask what is not only possible but necessary for architecture in our time. The course is envisaged as an upper level course in architectural theory, for both graduate and undergraduate students. Student work will involve reading, writing, and drawing.

**ARCH 712 402** Cultural Ecology: Recitation — ARCH 712-401 — 0

Recitation for Cultural Ecology

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|---|---|---|---|---|

**ARCH 734 001** Architecture & Ecology — Martin — 1

Building is an inherently exploitive act – we take resources from the earth and produce waste and pollution when we construct and operate buildings. As global citizens, we have an ethical responsibility to minimize these negative impacts. As creative professionals, we have a unique ability to go farther than simply being "less bad," We can learn to imagine designs that heal the damage and regenerate our environment. This course explores the evolving approaches to ecological design – from neo-indigenous to eco-tech to LEED to biomimicry to living buildings. Taught by a practicing architect with many years of experience designing green buildings, the course also features guest lecturers from complementary fields - landscape architects, hydrologists, recycling contractors and materials specialists. Coursework includes in-class discussion, short essays and longer research projects.

**ARCH 751 001** Ecology, Technology, and Design — Braham — 1

The course draws on theories of ecological design and on the history and philosophy of technology to examine the complex interaction between the built and natural environments. The energy diagramming techniques of HT Odum are used as a common framework for projects in the course. Weekly lectures are supported by in-class and take home exercises, culminating in a final project.

**ARCH 752 001** Integrated Building Design — Martin — 1

As we push to improve environmental building design performance in areas such as energy & water consumption, carbon emissions, constructability/deconstructability, and occupant productivity, there is growing evidence that an integrative design approach is necessary. This course will focus on two factors that must be learned by the entire design and construction team for successful integrative design: systems thinking and effective collaboration. Students will work with guest lecturers who are architects, engineers, builders and others working at a high level of integration in their own work. The course will be a workshop format with the guests presenting actual design questions and working with students on integrative solutions. The goal is for students to understand how integrative thinking, collaboration and an understanding of the interactions of building systems and context can be used to achieve high levels of building performance.

**ARCH 753 001** Building Performance Simulation — Yi — 1

The course provides students with an understanding of building design simulation methods, hands-on experience in using computer simulation models, and exploration of the technologies, underlying principles, and potential applications of simulation tools in architecture. Classroom lectures are given each week, with a series of analysis projects to provide students with hands-on experience using computer models. This course is required for MEBD students.

**ARCH 754 001** Performance Design Workshop — Yi — 1

The workshop applies simulation techniques developed in Building Performance Simulation and diagramming techniques developed in ecology, technology and design to a series of discrete design projects at different scales. The emphasis is on refinement and optimization of performance based design. This course is required and reserved for MEBD students.

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## Spring 2012 Course Descriptions

| Course No. | Course Title | Co-Req | Instructor | CUs |
|---|---|---|---|---|

**ARCH 756 401** Policy and Design: Next Generations Codes — Hughes — 1

This year's Policy and Design seminar will focus on next-generation building regulation, especially energy codes related to both new and existing buildings. In addition to exploring the seminar's regular theme of the relation between design thinking and policy development, this year's seminar will investigate standard and best practices in how the energy performance of buildings is regulated, especially through building codes. The primary product of the seminar will be a multi-year research agenda on next-gen building codes with a focus on the technical, political, and organizational challenges to making these aspirational policies a reality in the U.S. The seminar will be embedded in the work of the new DOE energy hub at the Navy Yard know as GPIC, will work closely with the symposia scheduled this spring at the Garrison Institute (including fully funded attendance by all students in one of three symposia at the Institute's Hudson Valley retreat), and will involve guest seminars by former Overseer Jonathan Rose, Overseer Chuck Leitner, and other thought and practice leaders from the regional and national scenes.

**ARCH 757 001** Buildings and Behavior: Bringing the IGCC to — Hughes — 1

Buildings, as both a process and a product, are a critical focus of current policy on energy and climate change. Behaviors are seen as an input to the technology of buildings, often as a constraint on the efficient performance of that technology. Simultaneously, behaviors are seen as an output of buildings: measured by productivity, satisfaction, health, and so on. New approaches are under development to connect these into an integrated system, in which buildings and behavior can continuously improve each other through monitoring, feedback, and adaptation. One of the most ambitious of these approaches is the new International Green Construction Code from the International Code Council in partnership with ASTM, AIA, USGBC, and others. The IGCC “was created with the intent to be administered by code officials and adopted by governmental units at any level on a mandatory basis. It is designed to drive green and sustainable building significantly beyond the market segment that has been transformed by voluntary rating systems.” Thus, IGCC implicates behavioral changes on many levels: from adoption by legislators to the practice of designers to the occupancy of owners and tenants. The seminar will review the latest behavioral research with a focus on buildings and then use the Navy Yard (recently chosen as the site of the new DOE Energy Efficient Buildings Hub) as a simulator of implementing IGCC in a real place. What would it take to bring the Navy Yard of to code under the provisions/ambitions of the IGCC? Students will develop Navy Yard proposals based on

**CPLN 531 001** Introduction to Environmental Planning & Policy — Daniels — 1

Overview of national programs for protecting the environment, managing natural resource areas, preserving biodiversity, and remediating brownfields, in an overall framework based on sustainability. covers basic principles of geology, hydrology, limnology, and climatology, Oregon's Land Use Transportation Air Quality (LUTRAQ) connection, environmental impact assessment, environmental justices.

**CPLN 641 001** Progressive Development — Landis

Using a case study approach, this course will teach students how to plan, develop, and finance a variety of progressive real estate development forms including affordable, senior, and workforce housing; transit-oriented development; urban mixed-use development; green and LEED certified office, retail, and housing projects; sustainable master-planned communities; and public-private partnerships.

**EAS 501 401** Energy & its Impacts — Lior — 1

The objective is to introduce students to one of the most dominating and compelling areas of human existence and endeavor: energy, with its foundations in technology, association to economics, and impacts on ecology and society. This introduction is intended both for general education and awareness and for preparation for careers related to this field. The course spans from basic principles to applications. A review of energy consumption, use, and resources; ecological impacts, sustainability and design of sustainable energy systems; methods of energy analysis; forecasting; electricity generation systems (steam and gas turbine based power plants, fuel cells), energy for transportation (cars, aircraft, and ships); nuclear energy and wastes; renewable energy use: solar, wind, hydroelectric, geothermal, biomass; prospects for future energy systems: fusion power, power generation in space.

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## Spring 2012 Course Descriptions

| Course No. | Course Title | Co-Req | Instructor | CUs |
|---|---|---|---|---|
| **EAS 502 401** | Renewable Energy & its Impacts | | Lior | 1 |

The objective is to introduce students to the major aspects of renewable energy, with its foundations in technology, association to economics, and impacts on ecology and society. This introduction is intended both for general education and awareness and for preparation for careers related to this field. The course spans from basic principles to applications. A review of solar, wind, biomass, hydroelectric, geothermal energy, and prospects for future energy systems such as renewable power generation in space.

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| **EAS 503 401** | Energy Systems & Policy | | Huemmler | 1 |

This is a survey course that will examine the current U.S. energy industry, from production to consumption, and its impacts on local, regional, and the global environment. The course will seek to provide a fuller understanding of existing energy systems, ranging from technical overviews of each, a review of industry organization, and an exploration of the well-established policy framework each operates within. Near-term demands upon each energy supply system will be discussed, with particular focus on environmental constraints.

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| **EAS 505 401** | Climate Policy & Tech | | Huemmler | 1 |

The course will exam Pacala and Socolow's hypothesis that "Humanity already possesses the fundamental scientific, technical and industrial know-how t solve the carbon and climate problem for the next half-century." Fifteen "climate stabilization wedges" i.e., strategies that each have the potential to reduce carbon emissions by 1 billion ons per year by 2054, will be examined in detail. Technology and economics will be reviewed. Socio-political barriers to mass-scale implementation will be discussed. Pacala and Socolow note "Every element in this portfoloio has passed beyond the laboratory bench and demonstration project; many are already implemented somewhere at full industrial scale".

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|---|---|---|---|---|
| **ENVS 494 660** | Toward Environmental Sustainability On Penn's | | Garofalo | 1 |

In a February 5, 2007 press release President Amy Gutmann stated that Penn will develope a "comprehensive sustainability plan by 2009.This includes completing a comprehensive inventory of all its greenhouse gas emissions; purchasing at least 15 percent of its electricity from renewable sources; adopting an energy efficient appliance purchasing program; committing to a policy that new construction be built to the US Green Building Council LEED Silver standards, or equivalent; and providing access to public transit for faculty, students, and staff." This course will examine Penn's "environmental footprint",what is being done to reduce this footprint, and present ideas for further improvements. The students will build on the work of others, document existing efforts, and benchmark against other universities. The course will explore the issues mentioned above and will also address issues such as stormwater management, the greening of campus, and leadership in the nearby community. The students will establish baseline data and measurement strategies so that success can be measured, and then will develop strategies to collect and analyze additional data. Included in the course will be the concepts of environmental management systems, secondary impacts ?eg, commuting habits of Penn employees?, pollution prevention, and life-cycle analysis. Each student or group of students, will select sn area of focus for their research exercise ?eg, energy, recycling, green buildings? and develop a report that can be used by the Penn administration to advance Penn's efforts toward sustainability. The

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| **HSPV 516 001** | Building Diagnostics | | Henry | 1 |

Building diagnostics pertain to the determination of the nature of a building's condition of performance and the identification of the corresponding causative pathologies by careful oberservation and investigation of its history, context and use. Monitoring, a building diagnostic tool, is the consistent observation and recordation of a selected condition or attribute, by qualitative and/or quantitative measures over a period of time in order to generate useful information or data for analysis and presentation. Building diagnostics and monitoring allow the building professional to identify the causes and enabling factors or past or potential pathologies in a building and building systems, thus informing the development of buildings, the process informs the selection of interventions that satisfy the stewardship goals for cultural resource.

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## Spring 2012 Course Descriptions

| Course No. | Course Title | Co-Req | Instructor | CUs |
|---|---|---|---|---|
| **HSPV 551 001** | Building Pathology | | Henry | 1 |

This course addresses the subject of building deterioration and intervention, with the emphasis on the technical aspects of deterioration. Construction and reconstruction details and assemblies are analyzed relative to functional and performance characteristics. Case studies cover subsurface conditions, structural systems, wall and roof systems, and interior finishes with attention to performance, deterioration, and stabilization or intervention techniques.

**LARP 760 001** Topics in Eco Design 1

These elective courses explore relevant topics in ecological design and new technologies as they relate to contemporary landscape architecture. The course explores topics such as ecology, sustainability, habitat restoration, hydrology, green roof and green architecture technology, soil technology, and other techniques pertinent to the construction of ecologically dynamic, functioning landscapes. The teaching faculty are leading practitioners and researchers in the field. These courses are open to all interested PennDesign students

**LGST 815 401** Environmental Management Law & Policy Orts

This course provides an introduction to environmental management with a focus on law and policy as a basic framework. The primary aim of the course is to give students a deeper practical sense of the important relationship between business and the natural environment and to think critically about how best to manage this relationship.