February 29, 2024

Sanjay Rai, PhD
Secretary
Maryland Higher Education Commission
6 N. Liberty Street, 10th Floor
Baltimore, MD 21201

Dear Secretary Rai,

On behalf of Provost Jayawardhana, I write to request your review and endorsement of the enclosed proposal. The university proposes a new **Master of Science in Climate, Energy, and Environmental Sustainability.**

The proposed Master of Science in Climate, Energy, and Environmental Sustainability will provide valuable knowledge to engineers, scientists, managers, and practicing climate change professionals to design and implement rigorous and strategic solutions to global environmental, energy, social, and economic challenges. The program will also provide students with the broad expertise needed to enter and/or advance public and private sector activities related to energy, sustainability, and climate change planning and management.

The proposed program is consistent with the Johns Hopkins mission and the State of Maryland's Plan for Postsecondary Education. The proposal is endorsed by The Johns Hopkins University.

Should you have any questions or need further information, please contact Westley Forsythe at (410) 516-0188 or wforsythe@jhu.edu.

Thank you for your support of Johns Hopkins University.

Sincerely,

Janet Simon Schreck, PhD
Senior Associate Vice Provost for Academic Affairs

cc: Dr. Ray Jayawardhana

Dr. Westley Forsythe

Enclosures

Office Use Only: PP#

Cover Sheet for In-State Institutions
New Program or Substantial Modification to Existing Program

Institution Submitting Proposal	The Johns Hopkins University

Each action below requires a separate proposal and cover sheet.

- (◉) New Academic Program
- ( ) New Area of Concentration
- ( ) New Degree Level Approval
- ( ) New Stand-Alone Certificate
- ( ) Off Campus Program
- ( ) Substantial Change to a Degree Program
- ( ) Substantial Change to an Area of Concentration
- ( ) Substantial Change to a Certificate Program
- ( ) Cooperative Degree Program
- ( ) Offer Program at Regional Higher Education Center

Payment Submitted:	(◉) Yes ( ) No	Payment Type:	( ) R*STARS # 12030848 (◉) Check # 12030848	Payment Amount:	$850	Date Submitted:	03/1/2024

Department Proposing Program	Whiting School of Engineering
Degree Level and Degree Type	Master of Science
Title of Proposed Program	Climate, Energy, and Environmental Sustainability
Total Number of Credits	30
Suggested Codes	HEGIS: CIP: 14.1401
Program Modality	( ) On-campus (◉) Distance Education (*fully online*) ( ) Both
Program Resources	(◉) Using Existing Resources ( ) Requiring New Resources
Projected Implementation Date	(◉) Fall ( ) Spring ( ) Summer Year: 2024
Provide Link to Most Recent Academic Catalog	URL: https://e-catalogue.jhu.edu/
Preferred Contact for this Proposal	Name: Westley Forsythe
	Title: Academic Compliance Officer
	Phone: (410) 516-0188
	Email: wforsythe@jhu.edu
President/Chief Executive	Type Name: Ray Jayawardhana
	Signature: Ray Jayawardhana Date: 02/02/2024
	Date of Approval/Endorsement by Governing Board:

Revised 1/2021

Master of Science in Climate, Energy, and Environmental Sustainability

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A. Centrality to Institutional Mission and Planning Priorities

1. Provide a description of the program, including each area of concentration (if applicable), and how it relates to the institution's approved mission

The Johns Hopkins University/Whiting School of Engineering is pleased to submit a proposal for a new Master of Science in Climate, Energy, and Environmental Sustainability. This program is an outgrowth of the established Master of Science programs in Environmental Engineering, Environmental Engineering and Science, and Environmental Planning and Management within the Whiting School of Engineering's Engineering for Professionals (JHU-EP) Program. This Master of Science in Climate, Energy, and Environmental Sustainability will be offered as an online program, making it available to a broader population of engineers and scientists seeking to understand and apply the concepts and methodologies of climate, energy, and environmental sustainability to real world situations.

The proposed Master of Science in Climate, Energy, and Environmental Sustainability will provide valuable knowledge to engineers, scientists, managers, and practicing climate change professionals to design and implement rigorous and strategic solutions to global environmental, energy, social, and economic challenges. The program will also provide students with the broad expertise needed to enter and/or advance public and private sector activities related to energy, sustainability, and climate change planning and management. Students will further their knowledge and skills in climate change, energy planning, and management; alternative energy technologies; transportation innovations curtailing atmospheric pollution; approaches for implementing sustainable development initiatives; resolving endemic social and behavioral challenges; evaluating next-generation buildings; selecting optimal air resource management strategies; assessing the benefits and costs of advanced pollution control technologies; and selecting approaches for enhancing global (and local) public health and environmental quality.

The mission of The Johns Hopkins University is to educate its students and cultivate their capacity for life-long learning, to foster independent and original research, and to bring the benefits of discovery to the world. The mission of the JHU Whiting School of Engineering is to provide educational programs of the highest quality that will attract the most qualified and driven students and faculty. The vision of the JHU Whiting School of Engineering is to be a world-recognized leader in engineering education, to lead in the creation and dissemination of knowledge, and to translate those educational and research activities into solutions to important societal problems. The proposed degree program aligns with both the mission of Johns Hopkins University and the mission of the Whiting School of Engineering as discussed below.

2. **Explain how the proposed program supports the institution's strategic goals and provide evidence that affirms it is an institutional priority**

A strategic priority of the JHU Whiting School of Engineering is to provide students with innovative and distinctive educational opportunities. Part of the mission of the JHU Whiting School of Engineering is to "provide an outstanding engineering education that is innovative, rigorous, and relevant, and that prepares its graduates to be 21st century leaders." The Whiting School of Engineering supports this mission by developing contemporary master's degree offerings for full- and part-time students, with flexible formats that respond to the needs of industry in both the domestic and international markets. An online program offers a flexible format and enables this program to more easily reach the international markets cited in this goal.

The Johns Hopkins University professional programs in the fields of engineering and applied science are among the oldest and largest in the United States. Administered by the Whiting School of Engineering through JHU-EP, this activity seeks to meet the lifelong education needs of working professionals in engineering and applied science. JHU-EP offers state-of-the-art courses combined with the convenience, flexibility, and accessibility that make these educational opportunities feasible for working adults.

In recent years, JHU-EP has moved steadily into the field of distance education, offering more and more courses online. This development meets two needs: (1) it contributes to the convenience and flexibility of existing offerings, by allowing students to take a mix of classroom and online courses, and (2) it opens this educational opportunity to a much larger market, enabling students throughout the country and, indeed, the world to take courses at Johns Hopkins University.

Johns Hopkins University is recognized as providing world-class education and research in engineering and applied mathematics and science. Through this online program, JHU-EP will continue its leadership role in preparing students with the knowledge and skills to apply climate, energy, and environmental sustainability concepts and methodologies to systems and processes in both industry and government. This degree will be coordinated by the JHU-EP program in the Whiting School of Engineering and the Applied Physics Laboratory.

Through this proposed degree, engineers and scientists will develop the skills needed to apply climate, energy, and environmental sustainability concepts and methodologies in the development of products and processes in the future. The program will provide in-depth knowledge and technical skills in the field of climate, energy, and environmental sustainability and prepare students for technically significant careers within industry and governmental organizations.

3. **Provide a narrative of how the proposed program will be adequately funded for at least the first five years of program implementation**

The JHU-EP Program sets aside a portion of its tuition revenue each year as part of its budgeting process to fund the development of new programs and new courses. In addition, the tuition revenue from enrollments in the courses in any program is used to cover the instructional costs of the program before any excess is used for other JHU-EP efforts. If a new program finds that its instructional costs are greater than the tuition revenue, funds are allocated from elsewhere in the overall JHU-EP Program to cover the startup program's shortfalls during the first five years. Additional related information is provided in section L.

4. **Provide a description of the institution's commitment to:**

   a. **Ongoing administrative, financial, and technical support of the proposed program**

      The best evidence for the commitment that the JHU-EP Program makes to its students and to their employers to maintain ongoing support for the administrative, financial, and technical support for this program is the history of the JHU-EP Program. Several EP master's degree programs have been in existence for over 50 years going back to the days of the JHU Evening College. The programs developed more recently have flourished as well. JHU-EP does a careful program viability study for new programs based on prospective student and employer feedback, as well as the sort of information provided elsewhere in this proposal addressing market demand. The Whiting School of Engineering greatly values these part-time graduate offerings and the impact that they provide to the engineering community and society. The proposed program would receive the same sort of administrative, financial, and technical support as the other programs in JHU-EP's portfolio.

   b. **Continuation of the program for a period of time sufficient to allow enrolled students to complete the program**

      The JHU-EP Program is committed to providing all enrolled students the opportunity to complete the degree program, including under circumstances of low demand. As in the previous section, a historical example is the best evidence for this commitment. In the early 2000s, the part-time undergraduate programs administered by JHU-EP were discontinued after six decades due to a reduction of interest in the programs by both employers and students. After ceasing enrollment of new students, the program developed plans for each remaining student to complete the degree at significant cost to JHU-EP, since many classes needed to be offered with only two or three students attending.

B. Critical and Compelling Regional or Statewide Need as Identified in the State Plan

1. **Demonstrate demand and need for the program in terms of meeting present and future needs of the region and the State in general**

   JHU-EP is focusing on the "need for advancement and evolution of knowledge" in the state of Maryland with this program. The Maryland Department of Labor Licensing and Regulation (DLLR), Maryland Long Term Occupational Projections (2020-2030) projects a need for 255 more environmental scientists and specialists (percent change of 9.8%) from 2020 to 2030.

2. **Provide evidence that the perceived need is consistent with the Maryland State Plan for Postsecondary Education**

   The proposed program is well aligned with the 2022 Maryland State Plan for Higher Education. The Master of Science in Climate, Energy and Environmental Sustainability is intended to prepare highly-trained scientists and engineers to work in organizations where they can contribute to the needs of society. The long-term success of JHU-EP programs for working professionals attests to the quality and effectiveness of these programs.

   Candidates can undertake course-related activities at a time and a location most convenient to them from any part of the state of Maryland. The online aspect allows students to participate in and to complete their program, even if their work schedules do not permit regular class attendance, thus supporting Goal 1, "Student Access: Ensure equitable access to affordable and high-quality postsecondary education for all Maryland residents."

   Similarly, the proposed program is consistent with Goal 2, "Student Success: Promote and implement practices and policies that will ensure student success." Students in the program will be supported by the Engineering for Professionals Student Academic Success Office, providing academic support (e.g., tutoring, success webinars, etc.) for those identified as being at risk to drop out. Further, the program will deliver highly-applicable education to industrial engineers and operations engineers in the State of Maryland, only improving workforce outcomes for the State and Maryland residents.

   Lastly, the proposed program is consistent with Goal 3, "Innovation: Foster innovation in all aspects of Maryland higher education to improve access and student success." Here again, the remote nature of the coursework and program will grant educational access to working professionals across the State of Maryland who would otherwise not be able to study in-person on a campus.

C. Quantifiable and Reliable Evidence and Documentation of Market Supply and Demand in the Region and State:

1. **Describe potential industry or industries, employment opportunities, and expected level of entry (*ex: mid-level management*) for graduates of the proposed program**

   The importance of climate, energy, and environmental sustainability appears to be on the rise. In 2021 the World Economic Forum released a report on Sustainable Development Impact. (https://www.weforum.org/events/sustainable-development-impact-summit-2021) Key findings noted in that report were:

   - Green skills are essential to the transition towards a green economy, with the ILO estimating 24 million jobs worldwide could be created by the green economy by 2030.
   - A shift towards green jobs is underway, with LinkedIn jobs data showing in 2015 the ratio of US oil/gas jobs to renewables/environment jobs was 5:1, but by 2020 this was 2:1.

- We are seeing green jobs span a wide range of industries, from obvious ones like renewables, to more unexpected ones like finance, fashion technologies and transport.

This proposed program will specifically provide a pathway for current engineers and scientists to retool themselves to meet these challenges.

Job titles that relate to climate, energy, and environmental sustainability are environmental engineer, environmental scientist, and environmental protection specialist. Web searches for jobs with these titles reveal hundreds of opportunities available at numerous organizations. All these job opportunities could be filled by graduates of this proposed program. It is expected that the program will provide entry-level worker, mid-level manager and senior manager graduates for the workforce.

2. Present data and analysis projecting market demand and the availability of openings in a job market to be served by the new program

According to the Bureau of Labor Statistics (BLS), nationwide employment of environmental engineering occupations is projected to grow 4.2 percent from 2021 to 2031. Pursuing a degree like this Master of Science in Climate, Energy, and Environmental Sustainability is a significant way to maintain career viability. Job opportunities for the graduates of this program include positions in corporations and government organizations.

Based on the projected market demand and the accessibility and convenience of an online program, we expect this degree program to be successful.

3. Discuss and provide evidence of market surveys that clearly provide quantifiable and reliable data on the educational and training needs and the anticipated number of vacancies expected over the next 5 years

As noted in sections C.1 and C.2 above, environmental engineering as an occupation shows strong growth in the next ten years. Web searches for related job postings revealed hundreds of job openings nationwide. We expect the interest from students in this Master of Science in Climate, Energy, and Environmental Sustainability to be strong.

4. Provide data showing the current and projected supply of prospective graduates

There is no other degree like this proposed degree in the State of Maryland so there were no graduation data for this degree on the Maryland Higher Education Commission website.

D. Reasonableness of Program Duplication

1. Identify similar programs in the State and/or same geographical area. Discuss similarities and differences between the proposed program and others in the same degree to be awarded

We conducted a side-by-side analysis of the proposed JHU Climate, Energy, and

Environmental Sustainability program with the following degrees in the State of Maryland:

- Goucher College, M.A. in Environmental Sustainability and Management
- Frostburg State University, M.S. in Environmental Management in Sustainability
- University of Maryland Baltimore County, M.S. in Environmental Engineering

The analysis included admissions criteria, program learning outcomes, degree criteria, and courses offered.

The program offered at Goucher College (M.A. in Environmental Sustainability and Management) appears to be management and policy-focused judging by the course offerings and the title of the program. The program does not identify specific levels of math and science as admission requirements.

The program offered at Frostburg State University (M.S. in Environmental Management in Sustainability) focuses on environmental science, management, and planning, as evidenced by the fact that nearly all courses offered are in these areas. Further, the Program Learning Outcomes are stated as follows:

- A fundamental understanding of one or more chosen environmental and/or associated social science disciplines.
- An understanding of environmental field sampling methods, constraints, and analyses.
- An ability to synthesize and communicate environmental science for management purposes.
- An ability to work in and/or lead teams of environmental scientists and managers.
- An ability to apply environmental science in a workplace setting and produce a professional final report.

The program offered at the University of Maryland Baltimore County (M.S. in Environmental Engineering) is a traditional environmental engineering program emphasizing water resources as specified below:

"The Environmental Engineering (ENEN) Program emphasizes research in environmental engineering and water resources. Environmental engineers identify and design solutions for environmental problems, such as providing safe drinking water, treating and safely disposing of wastes, controlling water pollution, maintaining air quality, and remediating contaminated sites."

The core courses listed for this degree are:

ENEN 610 Environmental Chemistry
ENEN 612 Environmental Physicochemical Processes
ENEN 614 Environmental Biological Processes
ENEN 660 Air Pollution

"The M.Res in Sustainability at Capitol Technology University asserts itself as a research degree for established professionals, differentiating it JHU's proposed offering. Additionally, JHU's proposed degree provides curriculum designed for engineering professionals seeking to apply engineering principles and scientific approach to sustainability challenges.

The proposed JHU M.S. in Climate, Energy, and Environmental Sustainability has a different focus than these programs as articulated in the program objectives and the breadth of courses offered. The proposed program is centered on the engineering, science, and technical aspects of these emerging and interconnected fields. The Johns Hopkins program contains a very strong emphasis in the areas of climate and energy sustainability -- stress areas that do not appear as frequently in the course offerings of the other degree programs noted above. There is enough differentiation in the name, focus, and admission requirements to indicate that the new program will generate a new market of students entering a program in the State of Maryland. We have been cognizant to steer away from unnecessary overlaps with the programs listed aove.

2. Provide justification for the proposed program

This Master of Science in Climate, Energy, and Environmental Sustainability is unique in terms of the content and offering modality. The broad set of online climate, energy, and environmental sustainability courses available to engineers and scientists will attract a broad range of students. JHU is highly regarded as having expertise in these areas by practitioners and researchers alike, such that the value proposition of reputation, quality, and convenience is readily understood. In view of the market demand for such a program, the online offering of the JHU-EP Master of Science in Climate, Energy, and Environmental Sustainability clearly meets a currently-important need in the region.

E. Relevance to High-demand Programs at Historically Black Institutions (HBIs)

1. Discuss the program's potential impact on the implementation or maintenance of high-demand programs at HBIs

There is no comparable degree program offered at any of the Historically Black Institutions in Maryland.

F. Relevance to the identity of Historically Black Institutions (HBIs)

1. Discuss the program's potential impact on the uniqueness and institutional identities and missions of HBIs

The proposed program would not directly affect the implementation, maintenance, uniqueness, identity, or mission of these institutions.

G. Adequacy of Curriculum Design, Program Modality, and Related learning outcomes (as outlined in COMAR 13B.02.03.10):

1. Describe how the proposed program was established, and also describe the faculty who will oversee the program

This Master's Degree Program in "Climate, Energy, and Environmental Sustainability" is an enhanced and extended curriculum of the existing Graduate Certificate in "Climate Change, Energy, and Environmental Sustainability."

The Master's degree program was first conceived when discussions between the JHU-EP Environmental Engineering program chair, the JHU-EP administration, the Program Committee, and the current faculty discerned a need for such a degree program. Over the past few months, the plans for this program were developed resulting in this degree proposal. The qualifications of the faculty who will oversee this program are provided in Appendix B. Program oversight will be provided by Whiting School of Engineering faculty members.

2. **Describe educational objectives and learning outcomes appropriate to the rigor, breadth, and (modality) of the program**

Educational Objectives

After graduation, graduates from this program will be able to:

- Apply climate, energy, and environmental sustainability theoretical concepts and practical methodologies in the development of systems and processes to provide solutions to impacts to both the built and natural environment.

Student Learning Outcomes

By the end of this program, students will be able to:

- Understand the foundations of sustainability and its impact on environmental, economic and social systems.
- Direct the development of solutions to problems affecting climate, energy use and availability and their impact on environmental sustainability.
- Explore the interdisciplinary aspects of environmental sustainability in science, public health, and society.
- Design and implement rigorous and strategic solutions to global environmental, energy, social, and economic challenges.
- Lead or advance public and private sector activities related to energy, sustainability, and climate change planning and management.

3. **Explain how the institution will:**

   a. **Provide for assessment of student achievement of learning outcomes in the program**

   During the design of the program's courses, the instructional designers on the JHU-EP staff assist the instructors in preparing learning assessments (assignments, projects, papers, exams, etc.) that are carefully linked to the program's learning outcomes. The instructors then grade these assessments using grading rubrics. The assessment grades indicate the achievement level of each learning outcome.

   b. **Document student achievement of learning outcomes in the program**

   The learning assessment scores are retained for the purposes of accreditation and program improvement. Grades are kept in the gradebook in Canvas and in separate learning assessment scorecards that are submitted to the EP Associate Vice Dean for Professional Education and Lifelong Learning at the end of each academic year. If learning outcomes are not met in a given year, the program is expected to change the way the outcome is taught in the related class and then reassessed post adjustment.

4. **Provide a list of courses with title, semester credit hours and course descriptions, along with a description of program requirements**

A full course listing with course titles and descriptions is provided in Appendix A. All JHU-EP courses are three (3) credits.

Admission Requirements

General admission requirements for master's degree candidates and others seeking graduate status are as follows: applicants must be in the last semester of undergraduate study or hold a bachelor's degree from a regionally accredited college or university.

In addition, applicants for the Master of Science in Climate, Energy, and Environmental Sustainability degree will have prior educational experience that must include the following prerequisite courses: Calculus I-II. Successful completion of college-level courses in physics, chemistry, biology, geology, and statistics is strongly recommended. Applicants whose prior education does not include the prerequisites listed above may still enroll under provisional status, followed by full admission status once they have completed the missing prerequisites. Missing prerequisites may be completed with Johns Hopkins Engineering or at another regionally accredited institution. Applicants typically have earned a grade point average of at least 3.0 on a 4.0 scale (B or above) in the latter half of their undergraduate studies. Transcripts from all college studies must be submitted. When reviewing an application, the candidate's academic and professional background will be considered.

Degree Requirements

To earn a Master of Science in Climate, Energy, and Environmental Sustainability, the student must complete 10 courses (30 approved credit) within five years. All courses are for three (3) credit hours. In addition, all the following must be satisfied:

- Minimum of five (5) courses from the student's designated program area (15 credits)

  Program areas:
  - Climate, Energy, and Environmental Sustainability
  - Environmental Engineering
  - Environmental Engineering and Science
  - Environmental Planning and Management

- Maximum of five (5) elective courses (15 credits) from any of the other three program areas.

- The following is a sample list of courses in the "Climate, Energy, and Environmental Sustainability" program area from which at least five (5) of the ten (10) courses must be completed:

  EN.575.623 Industrial Processes and Pollution Prevention

  EN.575.658 Natural Disaster Risk Modeling

  EN.575.711 Climate Change and Global Environmental Sustainability

  EN.575.721 Air Quality Control Technologies

  EN.575.722 Principles of Air Quality Management

  EN.575.723 Sustainable Development and Next-Generation Buildings77

  EN.575.732 Energy Technologies for Solving Environmental Challenges

EN.575.733 Energy and the Environment
EN.575.734 Smart Growth Strategies for Sustainable Cities
77EN.575.736 Designing for Sustainability: Applying a Decision Framework
EN.575.738 Transportation Innovation and Climate Change
EN.575.743 Atmospheric Chemistry7
EN.575.750 Environmental Policy Needs in Developing Countries
EN.575.771 Data Analytics in Environmental Health and Engineering
EN.575.801 Independent Project in Environmental Engineering, Science, and Management

- The Principles of Environmental Engineering (575.604) course is required of all degree students who do not possess an undergraduate degree in Environmental Engineering, Science, and Management or a related discipline.
- Only one (1) C-range grade (C+, C, or C-) may be counted toward the master's degree.
- Program chair approval of any deviation from this program, including transfer of courses and any other requisites specified in the student's admission letter.

The courses available in the four program areas are listed in Appendix A.

5. Discuss how general education requirements will be met, if applicable

Not applicable.

6. Identify any specialized accreditation or graduate certification requirements for this program and its students

Not applicable.

7. If contracting with another institution or non-collegiate organization, provide a copy of the written contract

Not applicable.

8. Provide assurance and any appropriate evidence that the proposed program will provide students with clear, complete, and timely information on the curriculum, course and degree requirements, nature of faculty/student interaction, assumptions about technology competence and skills, technical equipment requirements, learning management system, availability of academic support services and financial aid resources, and costs and payment policies

All specific course-related information (e.g., course requirements, nature of faculty/student interaction, assumptions about technology competence and skills, and technical equipment requirements) is provided in the syllabus for each course and is available on the Canvas course site. Program-related information (e.g., degree requirements, learning management system information, availability of academic support services, financial aid resources, and tuition payment policies) can be found both on the JHU-EP website (http://ep.jhu.edu) and as well as in the Engineering for Professionals

Academic Catalog (https://ep.jhu.edu/student-services/academic-services/academic-catalogs/).

Provide assurance and any appropriate evidence that advertising, recruiting, and admissions materials will clearly and accurately represent the proposed program and the services available.

The JHU-EP website (http://ep.jhu.edu) contains the same marketing, recruiting and admission materials that are used in print or other form and made available to the students. The JHU-EP academic catalog, which is available on the website, also contains the same material. We affirm that these materials represent a good faith effort to be totally clear and transparent in all our communications with current and new students. Incidentally, the need for clear and accurate program descriptions is also critical to the employers who are a very important factor in supporting our students in their academic pursuits.

H. Adequacy of Articulation

Not applicable.

I. Adequacy of Faculty Resources (as outlined in COMAR 13B.02.03.11).

1. **Provide a brief narrative demonstrating the quality of program faculty. Include a summary list of faculty with appointment type, terminal degree title and field, academic title/rank, status (full-time, part-time, adjunct) and the course(s) each faulty member will teach (in this program)**

   See Appendix B for a representative list of faculty who will teach in the proposed program. The program has identified highly qualified faculty members. Each is a distinguished and experienced professional, and all have advanced degrees (MS, DSc, or PhD) in their fields of expertise. Each has demonstrated a strong commitment to excellence in teaching. Most are associated with the nationally renowned Department of Environmental Health and Engineering, hosted jointly in the Whiting School of Engineering and the Bloomberg School of Public Health at Johns Hopkins University, or other universities, government agencies, and technology companies in the region. Many hold influential positions in their organizations. The JHU-EP program provides engineering education rooted in practice by relying heavily on practitioner faculty members.

2. **Demonstrate how the institution will provide ongoing pedagogy training for the faculty in evidenced-based best practices, including training in a. Pedagogy that meets the needs of the students, b. The learning management system and c. Evidenced-based best practices for distance education, if distance education is offered**

   Faculty support for the development and instruction of online courses is provided by the WSE Center for Learning Design and Technology (CLDT), consisting of 14 instructional design staff members and 12 multimedia technicians and instructional technology staff members. Faculty have multiple opportunities to receive training on the Canvas learning management system, and in the pedagogy of online learning. These opportunities are presented at various times throughout the year at events such as fall/spring annual faculty meetings, training webinars, and privately scheduled training sessions. Once an instructor has been identified to develop an online course, they are given access to a set of web-based resources that cover a broad range of topics on online pedagogy, use of instructional technologies and learning management system tutorials. Throughout the online course development, the instructor receives direct support and guidance from their assigned instructional designer, as well as from the instructional technology and multimedia staff. This could take the form of course design guidance based on best practices in online learning, course production support, and audio and video recording support. Once the course is built, the support staff continues to help the faculty member, offering best practices in course instruction and help desk support. After the course runs, these teams help the instructor make updates and improvements to the course.

J. Adequacy of Library Resources (as outlined in COMAR 13B.02.03.12).

Students have access to the Milton S. Eisenhower Library on the Homewood campus, which is ranked as one of the nation's foremost facilities for research and scholarship. Its collection of more than three million bound volumes, several million microfilms, and more than 13,000 journal subscriptions has been assembled to support the academic efforts of the University. The interlibrary loan department makes the research collection of the nation available to faculty and students. The library also provides easy access to a wide selection of electronic information resources, including the library's online catalog, and numerous electronic abstracting and indexing tools. Many of the databases are accessible remotely. Librarians help students electronically and the library maintains an extensive web site to take visitors through all its services and materials. To this are added more than 10,000 audiovisual titles available for on-site consultation.

K. Adequacy of Physical Facilities, Infrastructure and Instructional Equipment (as outlined in COMAR13B.02.03.13)

1. **Provide an assurance that physical facilities, infrastructure and instruction equipment are adequate to initiate the program, particularly as related to spaces for classrooms, staff and faculty offices, and laboratories for studies in the technologies and sciences. If the program is to be implemented within existing institutional resources, include a supportive statement by the President for adequate equipment and facilities to meet the program's needs**

   All required courses in the proposed program will be offered online. The program will have no discernible impact on the use of existing facilities and equipment beyond the standard requirements already in place. See additional details in section K.2 below.

2. **Provide assurance and any appropriate evidence that the institution will ensure students enrolled in and faculty teaching in distance education will have adequate access to a) an institutional electronic mailing system, and b) a learning management system that provides the necessary technological support for distance education**

a) All JHU students receive an Office 365 account including email capabilities (built on Outlook Live), as well as 25GB of online storage, collaboration, blogging, photo-sharing, event-planning, instant messaging, and other tools. The email account is accessible from a variety of browsers on both the PC and Mac, including full support for Edge, Firefox, Google Chrome, and Safari.

b) This program will be delivered via JHU-EP's online programs infrastructure, which includes the Canvas course management system and the Zoom video conferencing system. These technologies are supported by the Whiting School and the university's IT infrastructure and provide password-protected online course sites and community management systems that enable ongoing collaborative exchange and provide convenient channels for synchronous and asynchronous learning. Canvas is one of the world's leading providers of e-learning systems for higher education institutions. This software focuses on educational outcomes and provides a highly flexible learning environment for students. Johns Hopkins is also outfitted with suitable technical and professional staff and a help desk to provide technical assistance to the students taking online courses. All the student services such as application processes, course registration, bookstore, ID service, and advising are currently provided online as well.

The Whiting School already successfully delivers all its online and web-enhanced courses and programs using the above-mentioned platforms. As part of the program's development, the school's technical support team and business office have determined that JHU-EP possesses the necessary technology infrastructure and resources in place to support successful delivery of this online program.

L. Adequacy of Financial Resources with Documentation (as outlined in COMAR 13B.02.03.14)

Please see Appendix C.

M. Adequacy of Provisions for Evaluation of Program (as outlined in COMAR 13B.02.03.15).

1. Discuss procedures for evaluating courses, faculty and student learning outcomes

Once the Master of Science in Climate, Energy, and Environmental Sustainability program is launched, its courses will enter the course evaluation system. Students in all JHU-EP courses receive two evaluations each term -- one after the first half and one at the end of the term. These evaluations ask students to reflect on the course structure, the course content, and the instructor's performance. Summary reports are reviewed by the faculty member, the program chair, and the JHU-EP administration to determine whether changes are necessary. The Program Committee will discuss these results as well to consider the broader context of the program's curriculum and course delivery mechanisms.

As described in section G.3, student learning outcomes are carefully and deliberately linked to in-class learning assessments (assignments, projects, papers, exams, etc.) throughout the curriculum. The instructors then grade these assessments using grading rubrics. The assessment grades indicate the achievement level of each learning outcome. If learning outcomes are not met in a given year, the program is expected to change the way the outcome is taught in the related class and then reassess post adjustment.

2. **Explain how the institution will evaluate the proposed program's educational effectiveness, including assessments of student learning outcomes, student retention, student and faculty satisfaction, and cost-effectiveness.**

   Procedures for evaluating student satisfaction, instructor effectiveness, and student learning outcomes are mentioned in sections G.3 and M.1. The data that the program chair and program committee will need to evaluate performance and develop action plans where deficiencies are identified will be provided by the JHU-EP administrative staff. Student retention will be monitored by the JHU-EP institutional research staff and reported to JHU-EP leadership. Faculty satisfaction will be monitored by the individual EP program chairs through frequent informal communication, and at least once per year during a formal program-wide faculty meeting. The cost-effectiveness of the program will be monitored by the JHU-EP finance team and reported to JHU-EP leadership.

N. Consistency with the State's Minority Student Achievement Goals (as outlined in COMAR13B.02.03.05).

Any student meeting the admissions requirements can apply to the Master of Science in Climate, Energy, and Environmental Sustainability. The program will work to help all accepted students improve their workplace competitiveness and reach their professional goals, an aim consistent with the State's minority student achievement goals.

O. Relationship to Low Productivity Programs Identified by the Commission:

Not applicable.

P. Adequacy of Distance Education Programs (as outlined in COMAR 13B.02.03.22)

1. **Provide affirmation and any appropriate evidence that the institution is eligible to provide Distance Education.**

   JHU-EP has decades of experience administering successful online graduate programs. The Climate, Energy, and Environmental Sustainability program will be supported in the same way as the other twenty online master's degree programs in the Whiting School of Engineering.

2. **Provide assurance and any appropriate evidence that the institution complies with the C-RAC guidelines, particularly as it relates to the proposed program**

   a) **Online learning is appropriate to the institution's mission and purposes**

      The mission of The Johns Hopkins University is to educate its students and cultivate their capacity for life-long learning, to foster independent and original research, and to bring the benefits of discovery to the world. More simply stated, it is "Knowledge for the world." An online delivery format is not just appropriate, but truly a critical requirement of disseminating knowledge to students who are unable to travel to the Baltimore campus.

The institution's plans for developing, sustaining, and, if appropriate, expanding online learning offerings are integrated into its regular planning and evaluation processes

JHU-EP has fully embraced online education, to the extent that when a new program is developed, it is fully expected that the program will be delivered through an online modality. This part-time online division now reports up to the Whiting School of Engineering's Vice Dean for Graduate Education and Lifelong Learning, who also oversees all full-time residential graduate programs. As such, online education has increased exposure to Whiting School of Engineering leadership and is included in long-term planning, including student and faculty support systems. There is a clear vision for JHU-EP's online education enrollment growth documented in the program's five-year budget plan.

b) Online learning is incorporated into the institution's systems of governance and academic oversight

Johns Hopkins University reviews new online program proposals using the same systems of governance and academic oversight as that for new on-site programs. Before being shared with the deans of all JHU academic divisions, all proposals must first undergo a review by internal academic bodies, including discussions of fit with School mission, program viability, program rigor, instructor quality, and redundancy with existing programs. For Whiting School of Engineering programs, this entails a review by the Whiting School Graduate Committee, a faculty body with representation from both the part-time online and full-time residential program faculty. If approved, a proposal is then forwarded to the Homewood Academic Council for review by faculty from both the Whiting School of Engineering and the Krieger School of Arts and Sciences. As discussed in M.1, once a program is launched, its courses will enter the course evaluation system. Students in all JHU-EP courses receive two evaluations each term -- one after the first half and one at the end of the term. These evaluations ask students to reflect on the course structure, the course content, and the instructor's performance. Summary reports are reviewed by the faculty member, the program chair, and the JHU-EP administration to determine whether changes are necessary. The Program Committee will discuss these results as well to consider the broader context of the program's curriculum and course delivery mechanisms. Lastly, JHU-EP, and all the programs that it offers, undergoes a rigorous review by the Homewood Academic Council faculty every five years.

c) Curricula for the institution's online learning offerings are coherent, cohesive, and comparable in academic rigor to programs offered in traditional instructional formats

In most cases, a JHU-EP program's online courses are first developed and run as on-site courses, and this provides a suitable benchmark for course rigor and workload. A formal online course development process is then used to support the development of all online courses. This process incorporates the Quality Matters™ research-based set of eight standards for quality online course design that help to ensure the academic rigor of the online course is comparable to or better than the traditionally offered course. A JHU-EP program is composed of courses that are appropriately sequenced to ensure students have adequate background for courses later in the program. Courses are offered frequently enough to ensure that students can complete a degree program within the 5-year maximum allowable timeframe. All JHU-EP courses have a maximum of 19 student enrollees so that students have adequate access to the instructor. Courses are built with components such as discussion boards to facilitate student-student and student-faculty interaction.

d) The institution evaluates the effectiveness of its online learning offerings, including the extent to which the online learning goals are achieved, and uses the results of its evaluations to enhance the attainment of the goals

As discussed in M.1, once a program is launched, its courses will enter the course evaluation system. Students in all JHU-EP courses receive two evaluations each term -- one after the first half and one at the end of the term. These evaluations ask students to reflect on the course structure, the course content, and the instructor's performance. Summary reports are reviewed by the faculty member, the program chair, and the JHU-EP administration to determine whether changes are necessary. The Program Committee will discuss these results as well to consider the broader context of the program's curriculum and course delivery mechanisms.

As discussed in G.3, during the design of the program's courses, the instructional designers on the JHU-EP staff assist the instructors in preparing learning assessments (assignments, projects, papers, exams, etc.) that are carefully linked to the program's learning outcomes. The instructors then grade these assessments using grading rubrics. The assessment grades indicate the achievement level of each learning outcome. The learning assessment scores are retained for the purposes of accreditation and program improvement. Grades are kept in the gradebook in Canvas and in separate learning assessment scorecards that are submitted to the EP Associate Vice Dean for Professional Education and Lifelong Learning at the end of each academic year. If learning outcomes are not met in a given year, the program is expected to change the way the outcome is taught in the related class and then reassess post adjustment.

e) Faculty responsible for delivering the online learning curricula and evaluating the students' success in achieving the online learning goals are appropriately qualified and effectively supported

Any new instructor recruited to teach online must meet the same qualifications as those teaching in a traditional site-based program. They must have a terminal graduate degree in a relevant field, and they must have professional experience related to the course content.

Faculty support for the development of online courses is provided by JHU-EP's Center for Learning Design and Technology (CLDT) professional staff consisting of 14 instructional designers and 12 multimedia technicians and instructional technologists. Faculty have multiple opportunities to receive training on the Canvas learning management system, and in the pedagogy of online learning. These opportunities are presented at various times throughout the year at events such as fall/spring annual faculty meetings, training webinars, and privately scheduled training sessions. Once an instructor has been identified to develop an online course, they are given access to a set of web-based resources that cover a broad range of topics on online pedagogy, use of instructional technologies and learning management system tutorials. Throughout the online course development, the instructor receives direct support and guidance from their assigned instructional designer, as well as from the instructional technology and multimedia staff. This could take the form of course design guidance based on best practices in online learning, course production support, audio and video recording support. Once the course is built, the support staff continues to help the faculty member, offering best practices in course instruction and help desk support. After the course runs, these teams help the instructor make updates and improvements to the course.

f) The institution provides effective student and academic services to support students enrolled in online learning offerings

JHU-EP maintains numerous web-based resources to inform prospective students on the information they may need as an online student. These resources include: JHU-EP main website (http://ep.jhu.edu) and the JHU-EP online catalog (https://ep.jhu.edu/student-services/academic-services/academic-catalogs/), which both include detailed programmatic information, academic support services, financial aid, costs, policies, etc. and specific information for online learning. As new online students are admitted, they're introduced to the JHU-EP program and procedures through the fully online New Student Orientation, that includes information on registration, student advising, ordering textbooks, the JHU email system, and other online student services. All students who enroll in an online course are also enrolled in the New Online Student Orientation module, which focuses on introducing students to techniques that will enable them to be successful in an online course and trains them on the Canvas learning management system. Lastly, all new students are enrolled in a mandatory Academic Integrity training course -- a zero-credit, zero-tuition course that is geared towards helping students avoid behaviors linked to plagiarism, cheating and other violations of academic integrity.

Students are assigned an advisor when accepted. Students can work individually with the advisor to develop a course of study that meets the requirements of the program and the career goals of the student. Courses that deviate from the program plan and have not been approved by an advisor may not count toward degree requirements. All advising can be received remotely.

Students have online access to the Milton S. Eisenhower Library on the Homewood campus, ranked as one of the nation's foremost facilities for research and scholarship. The interlibrary loan department allows students access to resources at any other university in the nation. The library also provides easy access to a wide selection of electronic information resources, including the library's online catalog, and numerous electronic abstracting and indexing tools. Many of the databases are accessible remotely. Librarians are available to assist students remotely and the library maintains an extensive website to take visitors through all its services and materials.

The Johns Hopkins University is committed to making all academic programs, support services, and facilities accessible to qualified individuals with disabilities. Students with disabilities who require reasonable accommodations can contact the JHU-EP Disability Services Administrator and receive support remotely.

The Johns Hopkins Student Assistance Program (JHSAP) is a professional counseling service that can assist students with managing problems of daily living. Stress, personal problems, family conflict, and life challenges can affect the academic progress of students. JHSAP focuses on problem solving through short-term counseling. Online students may call a phone number for consultation and will be directed to the appropriate resource or office. JHSAP services are completely confidential. The program operates under State and Federal confidentiality legislation and is HIPAA compliant.

g) The institution provides sufficient resources to support and, if appropriate, expand its online learning offerings

The JHU-EP program prepares a five-year budget every year that includes sufficient resources to maintain all online programs and expand offerings, if desired. The budget contains funding for marketing and recruitment for all programs as well as staffing all programs in terms of admissions services, students and faculty support services, finance and administration services, and instructional design and instructional technology services. The budget also contains funding for new program viability analyses, new program marketing launches, and new course development costs. Faculty and staff development costs are included, as described in greater detail in section P.2.f above.

The JHU-EP Program collaborates with central Johns Hopkins University Information Technology to provide a robust and scalable, but also flexible, technical infrastructure that serves student and faculty member needs. These programs are delivered via JHU-EP's online programs infrastructure, which includes the Canvas course management system and the Zoom video conferencing system. These systems provide password-protected online course sites and community management systems that enable ongoing collaborative exchange and provide convenient channels for synchronous and asynchronous learning.

h) The institution assures the integrity of its online offerings

The Higher Education Opportunity Act (HEOA) enacted in 2008 requires that an academic institution that offers distance education opportunities to students 1) has a process established to verify that the student who registers is the same student who participates in and completes the offering and receives academic credit for it, 2) has a process established to verify that student privacy rights are protected, and 3) has a process established that notifies the student about any additional costs or charges that are associated with verification of student identity. In JHU-EP programs, the following actions have been taken to satisfy these requirements: 1) students may only enter the academic website for the online courses they take by providing the unique student ID and password assigned after admission, 2) all FERPA privacy rights are preserved by limiting access very specifically in the University student information system to only those permitted by law to have access to restricted student information, and 3) there are no additional costs assessed to the student for the measures we use to verify student identity.

Other measures are taken as well to assure the integrity of JHU-EP online offerings. The Whiting School of Engineering's Graduate Academic Misconduct Policy applies to all JHU-EP online students, it clearly defines misconduct, and it includes references to the most common online student infractions. As referenced in section P.2.g, all new JHU-EP students are enrolled in a mandatory Academic Integrity training course -- a zero-credit, zero-tuition course that is geared towards helping students avoid behaviors linked to plagiarism, cheating and other violations of academic integrity. Lastly, JHU-EP has recently required that all essay-based coursework be submitted to SafeAssign, a Canvas integrated tool used to prevent plagiarism by identifying unoriginal content and creating opportunities to help students identify how to properly attribute sources rather than paraphrase.

Appendix A
Course List and Descriptions

Courses in the Climate, Energy, and Environmental Sustainability Program Area

EN.575.623 – Industrial Processes and Pollution Prevention (3)
This course presents the pollution prevention and waste minimization concepts, terminologies, life cycle impacts, and management strategies. The course introduces available remediation techniques for industrial pollution control and prevention and examines specific applications to industries including biological, chemical, physical, and thermal techniques. Topics include current state of knowledge of pollution prevention approaches to encourage pollution prevention strategies, highlights of selected clean technologies and clean products, technical and economic issues, incentives and barriers to pollution prevention, and the role of different sectors in promoting pollution prevention. Pollution prevention and waste minimization techniques such as waste reduction, chemical substitution, production process modification, and reuse and recycling will be addressed regarding selected industries.

EN.575.658 – Natural Disaster Risk Modeling (3)
Natural hazards such as floods, earthquakes, and hurricanes exert a heavy toll of victims and economic losses every year. Yet, concentrations of population in hazard-prone-areas, the growth of infrastructure and climate change are aggravating the risk of future losses. Consequently, adequate interventions must be implemented to mitigate the damaging effects of natural hazards. To do this, public agencies, non-profits, and companies formulate mitigation actions such as emergency preparedness plans and building retrofits. Catastrophe models are tools to inform all these efforts, which simulate the socioeconomic risk resulting from the interaction of geophysical events and the spatial distribution of infrastructure.

EN.575.711 – Climate Change and Global Environmental Sustainability (3)
This is a multidisciplinary course that focuses on the critical assessment of science, impacts, mitigation, adaptation, and policy relevant to climate change and global environmental sustainability. The first half of the course introduces students to climate change including impacts and drivers, modeling science, mitigation and adaptation efforts, and social aspects (public opinion, responsibility, etc.). The second half of the class considers how climate change and sustainability relate and explores key sustainability concepts and trade-offs related to sustainability's three pillars of economy, society, and environment. Students will explore course concepts through a combination of materials including news and digital media and press, domestic and international technical reports, and peer-reviewed scientific literature. Discussions will include both physical and social considerations and cover a wide range of sectors (e.g., water, energy) and levels of governance (local, regional, national, international). Students will be required to use both subjective and objective analyses of course concepts through employing critical thinking strategies and active learning. Course assignments will include a combination of discussions, presentations, readings, and interactive exercises.

EN.575.721 – Air Quality Control Technologies (3)
This is a multidisciplinary course that involves the applications of chemistry, thermodynamics, and fluid mechanics in the selection and design of air pollution control equipment. Topics include the estimation of potential pollutants, chemical characterization of gas streams to be controlled, theory

and practice of air pollution control, and design and costing of control technologies. The course emphasizes the design of systems to reduce particulate matter emissions, volatile organic compound (VOC) emissions, nitrogen oxide emissions, and sulfur dioxide emissions.
Prerequisite(s): EN.575.601 Fluid Mechanics or an equivalent course in fluid flow; an undergraduate course in thermodynamics.

EN.575.722 – Principles of Air Quality Management (3)
Air quality is fundamental to human health and environmental stewardship. As science and technology evolve, our ability to protect and restore healthful air quality must address both long-standing and emerging issues. Air pollutants pose risks at multiple spatial scales, from individual homes to regional and global implications, and across various timelines - from hours to decades. This course provides a basic overview of the formation, transport, and transformation of air pollution as well as historical perspectives on the development of air pollution control programs. Emphasis is placed on utilizing measurements, analyzing emissions data, and exploring regulatory approaches. Air quality management principles are investigated that can enable a variety of strategies to minimize negative impacts of traditional and more recent air contaminants. Principles will be presented and applied to address ambient (outdoor) air pollution, indoor air quality, and climate change. The course includes a term project in which students will apply knowledge of the principles of air quality management to timely and relevant air quality issues.

EN.575.724 - Air Quality and Atmospheric Modeling (3)
This course will provide engineers and scientists an understanding of the principles of air quality modeling and practical experience coding, configuring, and running models in a variety of air quality scenarios. Air pollutant physical and chemical properties, in additional to equations of atmospheric motion, will provide a basis to understand model fundamentals. An air quality modeling framework will be utilized that consists of meteorological, emissions, and air quality models such as dispersion and photochemical models, types of each which will be investigated. Lagrangian and Eulerian frameworks will form the bases of regional and global scale modeling applications. Additional air quality models such as receptor models, global climate models and systems dynamics models will be introduced, and their application demonstrated in context. Students will build simple models from first principles as well as learn how to run and apply a complex air pollutant dispersion model. An emphasis will be placed on using air quality models as tools in air resources management decision making.
Prerequisite(s): EN.575.601 Fluid Mechanics or an equivalent course in fluid flow or hydraulics and 575.720 Principles of Air Quality Management

EN.575.723 – Sustainable Development and Next-Generation Buildings (3)
The course will introduce the concepts, applications, and tools for analysis and decision making in support of sustainable environmental development and next-generation communities and building design. Students will be introduced to a variety of challenges related to environmental protection, stewardship, and management of air, soil, and water. The underlying principles of ecological protection, stewardship, reduced environmental footprint, ecosystem capital, sustainable economic development, and globalization impacts will be reviewed. The integration of actions that are ecologically viable, economically feasible, and socially desirable to achieve sustainable solutions will be evaluated. Within this context, the course will explore sustainable building concepts that are intended to provide, throughout their lifetime, a beneficial impact on their occupants and their surrounding environment. Such buildings are optimally integrated on all parameters-initial affordability, timeliness of completion, net life-cycle cost, durability, functionality for programs and

persons, health, safety, accessibility, aesthetic and urban design, maintainability, energy efficiency, and environmental sustainability. The principles of LEED building design and certification will also be introduced with a review of example projects. Integrated design and construction practices that significantly reduce or eliminate the negative impact of buildings on the environment and occupants will be assessed in the broad areas of (1) sustainable site planning, (2) safeguarding water and water efficiency, (3) energy efficiency and renewable energy, (4) conservation of materials and resources, and (5) indoor environmental quality. A critical element for a successful sustainable building policy and program is an integrated building planning and design process. Integrated planning and design refer to an interactive and collaborative process in which all stakeholders are actively involved and communicate with one another throughout the design and construction practice. These processes will also provide a broader understanding of sustainable options for infrastructure changes that may occur in various BRAC planning and implementation situations. Several case studies will be examined to gain an understanding of application issues.

EN.575.732 – Energy Technologies for Solving Environmental Challenges (3)
This course covers the science, engineering, and operation of energy technologies – on a stand-alone and systems basis – that will reduce carbon dioxide and other greenhouse gas (GHG) emissions, and lower air pollution, with quantitative analysis where applicable. On the supply side, students will learn about solar radiation and its use for solar photovoltaic (PV) technologies (at a cell, module, and system-level) and concentrated solar power (CSP) with thermal storage, and other renewable energy technologies that use wind, water, and biomass, as well as the use of carbon capture and sequestration (CCS). Energy storage technologies covered to support variable renewable energy (VRE) integration include lithium-ion and other types of batteries, pumped hydro, compressed air energy storage (CAES), and longer-term energy storage from the production of hydrogen, using electrolysis and other low carbon methods. End-use energy technologies covered will include battery electric vehicles (BEV), plug-in hybrid (PHEV) and fuel cell electric vehicles (FCEV), and some examples of the use of low carbon heat sources or feedstocks for industrial processes and combined heat and power (CHP).

EN.575.733 – Energy and the Environment (3)
This course examines the interrelationships between the environment and the ways in which energy is produced, distributed, and used. Worldwide energy use patterns and projections are reviewed. Particular attention is paid to the electrical and transportation sectors of energy use. Underlying scientific principles are studied to provide a basis for understanding the inevitable environmental consequences of energy use. Topics studied include fossil, nuclear, and existing and potential renewable sources, including hydroelectric, geothermal, tidal, wind, and solar. Transportation options including internal combustion, hybrid, and electric options are quantitatively compared. Use of alternate fuels such as biodiesel and ethanol are evaluated. Emphasis is placed on the environmental impacts of energy sources, including local effects resulting from emissions of nitrogen oxides, sulfur, hydrocarbons, and particulates as well as global effects such as mercury release from coal combustion. Carbon emissions are a continuing theme as each energy technology is studied and its contribution to climate change is assessed. Carbon suppression schemes are examined. Particular attention is paid to the consequences and effectiveness of government intervention and regulation. The purpose is to help students understand how energy is converted into useful forms, how this conversion impacts our environment, and how public policy can shape these impacts.

EN.575.734 – Smart Growth Strategies for Sustainable Cities (3)
This course addresses the concepts, practices, and tools for smart growth sustainable urban planning and provides an understanding of how to apply these to urban communities. The sustainable urban development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present but also for future generations to come. In other words, it is the development and restoration of urban areas that will meet the needs of the present without compromising the ability of future generations to meet their own needs. The course addresses a number of urban design concepts for smart growth and sustainable development, including balanced land use planning principles; importance of an overall transportation strategy; providing urban tree coverage; leveraging public transportation accessibility; providing a spectrum of housing availability; integration of office, retail, and housing units; reduction of urban area environmental footprint; use of recycled, reused, reusable, green, and sustainable products; integration of renewable solar energy and wind power into buildings and government systems; transit-oriented development; innovative low-impact storm water management practices; reduction in urban heat island effects; urban water resource management; and energy efficiency and conservation.

EN.575.735 – Energy Policy and Planning Modeling (3)
This course provides students with comprehensive knowledge on methods for optimizing operation and design of energy systems and methods for analyzing market impacts of energy and environmental policies with emphasis on both theory and solution of actual models. The course also covers linear and nonlinear programming and complementarity methods for market simulation. *Prerequisite(s): Microeconomics or optimization methods (linear programming).*

EN.575.736 – Designing for Sustainability: Applying a Decision Framework
In this course, students will apply a sustainability decision framework, developed by the National Research Council, to an environmental project of their choice. This will include developing a project management plan, a project action plan, and an evaluation and adaptation assessment that will outline how sustainability principles will be incorporated into their project. This applied approach will give students experience in systems thinking, linkages across governmental bodies, development of indicators, use of environmental support tools, transdisciplinary cooperation, and the use of structured decision framework.

EN.575.738 – Transportation, Innovation, and Climate Change (3)
The world stands at the cusp of an unusually dynamic period in transportation's journey to the future. Legacy technologies coexist with powerful forces pushing forward revolutionary innovation. While cars and other vehicles using conventional fuels are forcing climate change, transportation innovations such as electric and automated vehicles to smart infrastructures are creating new lifestyles where transportation reduces carbon emissions. Transportation innovation creates technological and societal "tipping points" that will transform transport. Nevertheless, the direction and consequences of these "tipping points" are yet to be determined. In this class, students will test this thesis via the use of explanatory theories, risk models, and the evaluation of case studies of transport innovation. The use of these theories and tools will facilitate a more rigorous approach to anticipating the unintended, synergistic, and circular (feedback) effects of transportation innovation processes. Likewise, students committed to entering the fields of environmental planning and management will learn how to identify innovation strategies more likely to satisfy future unanticipated conditions and challenges. This course is divided into the following topics: 1) Mechanisms of climate change, 2) Role and efficacy of climate models, 3) Legacy transportation

technologies versus revolutionary transportation innovations, 4) Assessing alternative climate change futures through existing patterns of technological change and transportation innovation, 5) Identifying exogenous and endogenous threats and 6) Planning for the future through tools borrowed from a variety of disciplines (e.g., public participation, uncertainty and complexity studies, innovation roadmaps, and portfolio management).

EN.575.743 – Atmosphere Chemistry (3)
Earth's atmosphere is a vital and fragile component of our environment. This course covers the chemical composition of the atmosphere and the principles of chemistry that control the concentrations of chemical species. Following an introduction to the atmosphere, including its structure and composition, the course investigates basic concepts relating to atmospheric chemical kinetics and photochemistry. This foundation of chemistry and physics is applied to the study of the gas-phase chemistry of the troposphere and the stratosphere including focused study of criteria pollutants such as carbon monoxide (CO), tropospheric and stratospheric ozone (O3), chlorinated fluorocarbons (CFCs), sulfur and nitrogen oxides (NOx and SOx) and particulate matter (PM). Many trace species and their impacts on atmospheric chemistry are investigated. Condensed phase chemistry topics include aqueous-phase chemistry, the chemistry of clouds and fogs and aerosol chemistry (including particulate matter chemistry). The chemistry of climate change and the radiative forcing of atmospheric constituents is studied. The relationship between atmospheric chemistry and air quality is stressed via focusing on negative human health and environmental impacts. The course stresses the application of these concepts to current and relevant atmospheric chemistry issues.

EN.575.748 Water Quality Engineering with Green Infrastructure (3)
Topics in chemical, biological, and hydrological science necessary to understand water quality parameters and processes are reviewed. Mathematical models of fundamental processes that transport water pollutants and disperse them in the natural environment are presented in detail. Physical, chemical, and biological processes involved in water quality improvement technologies are covered and applied at the watershed scale to introduce green stormwater infrastructure technologies. Components of the Environmental Protection Agency's Storm Water Management Model (SWMM) model is presented along with theories and mathematical models of the underlying processes. Then, models are generated for eight of the primary green stormwater infrastructure technologies that are currently being installed in urban environments, and the model components within SWMM that implement these technologies are exercised. The course includes a "Green Infrastructure Watershed Implementation Project," to be conducted by individual students or small groups, that involves modeling and optimizing benefits and costs of a green infrastructure implementation program in an actual watershed chosen by the students.

EN.575.750 – Environmental Policy Needs in Developing Countries (3)
This course will provide students with a thorough understanding of environmental policy needs in developing countries. The world's fastest growing economies are located in developing countries where rapid urbanization and use of natural resources will require supporting infrastructure. However, there are factors that may encourage or limit this growth, including the country's economic structure, governance, cultural history, demographics, and social structure. Through lectures, research, and group exercises, the students will (1) explore the social, economic, and environmental issues that challenge countries in the developing world as they move toward advancing their economies, infrastructure, and governance systems; (2) analyze how the various issues are interconnected and understand how this interconnectedness may affect environmental

policy making; and (3) apply critical thinking to the analysis of environmental policy in order to effectively challenge classical assumptions. The student will be expected to analyze a specific environmental issue facing a developing country or region and develop a policy framework to address this issue.

EN.575.751 – Environmental Justice, Climate, and Health Equity (3)
Environmental planners are uniquely positioned to address climate change and improve public health. This course examines the impact of environmental planning on climate and public health, explores the emergence of environmental justice movements in the United States and globally, and offers students the knowledge and skills to apply policy-, community-, and movement-based strategies to solve current environmental and public health challenges.

EN.575.752 – Environmental Justice and Ethics in Environmental Decision-Making (3)
This course focuses on the environmental justice and ethics problems facing environmental engineers, planners, and managers. It explores the foundations of the environmental justice movement, current and emerging issues, and the application of environmental justice analysis to environmental policy and planning. It examines claims made by diverse groups along with the regulatory and government policy responses that address perceived inequity and injustice. The course will study the mechanisms that give rise to class, racial, and other kinds of disparities that impact environmental decision-making. This includes the study of affected constituents, communities, industry, government, environmental activists, policy makers, and scholars, allowing students to learn about the causes and consequences of inequitable distributions of environmental benefits and hazards. Students will learn about various methods for researching environmental justice issues and strategies for formulating policies and collaborating with communities. In this course, students will review environmental justice theories and perspectives through case studies of Black Americans, Hispanic Americans, and Native American Nations. The class will focus mainly on the United States, but will include aspects of international issues and perspectives through research projects.

EN.575.771 – Data Analytics in Environmental Health and Engineering (3)
Data analytics is a field of study involving computational statistics, data mining and machine learning, to explore data sets, explain phenomena and build models for inference and prediction. The course begins with an overview of some traditional analysis approaches including ordinary least squares regression and related topics, notably diagnostic testing, detection of outliers and methods to impute missing data. Next comes nonlinear regression, and regularization models including ridge regression. Generalized linear models follow, emphasizing logistic regression and including models for polytomous data. Variable subsetting is addressed through stepwise procedures and the LASSO. Supervised machine learning topics include the basic concepts of resampling, boosting and bagging and several techniques: Decision Trees, Classification and Regression Trees, Random Forests, Conditional Random Forests, Adaptive Boosting, Support Vector Machines and Neural Networks. Unsupervised approaches are addressed through applications using principal component analysis, k-means Clustering, Partitioning Around Medoids and Association Rule Mining. Methods for assessing model predictive performance are introduced including Confusion Matrices, k-fold Cross-Validation and Receiver Operating Characteristic Curves. Environmental and public health applications are emphasized, with modeling techniques and analysis tools implemented in R.

EN.575.801 – Independent Project (3)
This course provides students with an opportunity to carry out a significant project in the field of

environmental engineering, science, technology, planning, or management as a part of their graduate program. The project is individually tailored and supervised under the direction of a faculty member and may involve conducting a semester-long research project, an in-depth literature review, a non-laboratory study, or application of a recent development in the field. The student may be required to participate in conferences relevant to the area of study. To enroll in this course, the student must be a graduate candidate in the Environmental Engineering, Science, and Management Program within the latter half of the degree requirements and must obtain the approval and support of a sponsoring faculty member in the Department of Environmental Health and Engineering. The proposal description and completed required forms must be submitted prior to registration for approval by the student's advisor and the program chair. A maximum of one independent project course may be applied toward the master's degree or post-master's certificate.

Courses in the Environmental Engineering Program Area

EN.575.604 - Principles of Environmental Engineering (3)
This course addresses the wide range of environmental engineering fundamentals with quantitative analyses where applicable. Topics include mass and energy transfer and balances; environmental chemistry; mathematics of growth and decay; risk assessment and management; surface water pollutants, biological and chemical oxygen demands; eutrophication; water supply systems and drinking water standards; wastewater treatment systems and effluent standards; groundwater flow, contaminant transport, and remediation technologies; hazardous waste and pollution prevention; remedial and corrective actions at contaminated sites; air pollution sources, control technologies, and atmospheric stability; ambient air quality standards and indoor air quality; global temperature, greenhouse effect and warming potential; global energy balance, carbon emission, and stratospheric ozone depletion; solid waste management, landfill disposal, combustion, composting, and recycling; medical waste; and environmental law, ethics, and justice. Field trips are integrated into the classes.
Course Note(s): This course is required of all degree students studying environmental engineering, science, and management who do not possess an undergraduate degree in environmental engineering.

EN.575.605 – Principles of Water and Wastewater Treatment (3)
Water quality objectives and the chemical, physical, and biological processes necessary for designing and managing modern drinking water and wastewater treatment plants are described in the course. The principles of coagulation, flocculation, sedimentation, filtration, biological treatment, solids handling, disinfection, and advanced treatment processes are presented. The course serves as a basis for the more advanced courses: EN.575.745 Physical and Chemical Processes for Water and Wastewater Treatment, EN.575.706 Biological Processes for Water and Wastewater Treatment, and EN.575.746 Water and Wastewater Treatment Plant Design.
Prerequisite(s): EN.575.601 Fluid Mechanics or an equivalent course in fluid flow or hydraulics; two semesters of undergraduate chemistry.

EN.575.606 – Water Supply and Wastewater Collection (3)
This course covers the fundamental but practical issues of water distribution systems and wastewater/stormwater collection systems. Specific topics of interest in water supply include water supply master planning; design of water storage facilities, water mains, and pumping stations; distribution-system water quality; and service connection issues. Topics covered under wastewater/stormwater collection include hydrology and hydraulics of stormwater/wastewater conveyance systems; design of stormwater detention and retention facilities; and collection system

control technologies including green infrastructure. Also covered are regulations governing sanitary sewer overflows (SSOs) and combined sewer overflows (CSOs); public health, environmental, and economic impacts of SSOs and CSOs; sewer system evaluation and rehabilitation methods; stormwater best management practices; and the benefits and challenges of water reuse. Through research papers and discussion forums, students examine case studies that illustrate diverse practical situations and stimulate creative ideas for solving real-life design problems.
Prerequisite(s): EN.575.601 Fluid Mechanics or an equivalent course in fluid flow or hydraulics.

EN.575.607 – Radioactive Waste Management (3)
This course covers fundamental aspects of radioactive substances in the environment; remediation processes for these substances; and their eventual storage, processing, and disposal. It provides a basic understanding of radioactivity and its effect on humans and their environment, as well as the techniques for their remediation and disposal. Topics include radioactivity, the nucleoids, interaction of radiation with matter, shielding, dosimetry, biological effects, protection standards, sources of environmental radiation, risk evaluation, fate and transport analysis, cleanup standards, legal requirements, cleanup technologies, waste disposal, and case studies.

EN.575.620 – Solid Waste Engineering & Management (3)
This course covers engineering and scientific concepts and principles applied to the management of municipal solid waste (MSW) to protect human health and the environment and the conservation of limited resources through resource recovery and recycling of waste material. Topics include regulatory aspects and hierarchy of integrated solid waste management; characterization and properties of MSW; municipal wastewater sludge utilization; hazardous waste found in MSW; collection, transfer, and transport of solid waste; separation, processing, combustion, composting, and recycling of waste material; and the landfill method of solid waste disposal, which encompasses guidelines for design, construction, operation, siting, monitoring, remedial actions, and closure of landfills. Permitting and public participation processes, current issues, and innovative approaches are also addressed.

EN.575.703 – Environmental Biotechnology (3)
This course examines current applications of biotechnology to environmental quality evaluation, monitoring, and remediation of contaminated environments. The scale of technology ranges from the molecular to macrobiotic. Relevant topics of microbiology and plant biology are presented. These provide a foundation for subsequent discussions of microbial removal and degradation of organics, phytoremediation of soil and water contaminated with toxic metals and radionuclides, wetlands as treatment processes, biofilms/biofilters for vapor-phase wastes, and composting. Emphasis is placed on modeling and design. Advantages and disadvantages of each application are compared. Case studies are presented in the areas of biosensors in environmental analysis, molecular biology applications in environmental engineering, and genetic engineering of organisms for bioremediation.
Prerequisite(s): Prior coursework in environmental microbiology or biochemical engineering is recommended but not required.

EN.575.706 – Biological Processes for Water & Wastewater Treatment (3)
This course develops the fundamentals and applications of aerobic and anaerobic biological unit processes for the treatment of municipal and industrial wastewater. The principles of activated sludge, aeration and clarifier design, fixed film reactors, anaerobic treatment, solids handling, and treatment, land treatment, and nutrient removal are presented. This course uses concepts from microbiology and the basic principles of stoichiometry, energetics, and microbial kinetics are used to

support the design of biological unit processes.
Prerequisite(s): EN.575.601 Fluid Mechanics and EN.575.605 Principles of Water and Wastewater Treatment

EN.575.715 – Environmental Contaminant Dispersion and Transport (3)
This course provides an introduction to the concepts relating to the nature and sources of environmental contaminants in the subsurface, the role of groundwater and soil water in mobilizing and spreading contamination, the processes that control distribution and fate of subsurface contamination, the accepted methods of investigating and analyzing contamination, and the analytical techniques that can be employed to model contaminant fate and transport in the subsurface. The course also considers surface water contamination caused by contamination in the groundwater. Computer laboratories of groundwater model simulations and solute transport solutions are used.

EN.575.741 – Membrane Filtration Systems and Applications in Water and Wastewater Treatment (3)
This course covers fundamentals of membrane filtration technology and application in municipal and industrial water and wastewater treatment. Topics include membrane classification, mechanism of separation/filtration, principle of operation, performance monitoring, maintenance, pilot scale testing, residual disposal, emerging and developing membrane separation technologies, and regulations governing treatment objectives and residual disposal in membrane filtrations systems. This course provides students with in-depth knowledge of the theory, application, and design of membrane filtration systems by engaging them in group assignments and design projects.

EN.575.742 – Hazardous Waste Engineering and Management (3)
The course addresses traditional and innovative technologies, concepts, and principles applied to the management of hazardous waste and contaminated sites to protect human health and the environment. Topics include regulatory requirements; hazardous waste generators and transporters; permitting and enforcement of hazardous waste facilities; closure and financial assurance requirements; RCRA Corrective Action and CERCLA/Superfund/Brownfields site remediation processes; groundwater flow and fate and transport of contaminants; physical, chemical, and biological treatment; land disposal restrictions; guidelines for design, construction and closure of hazardous waste landfills; environmental monitoring systems; management of medical waste and treatment options; management of underground and aboveground storage tanks; toxicology and risk assessment; and pollution prevention and waste minimization.

EN.575.745 – Physical and Chemical Processes for Water and Wastewater Treatment (3)
In this course, mass and momentum transport, aquatic chemistry, and chemical reaction engineering are applied to physical and chemical processes used for water and wastewater treatment. Students also learn the theory and practice of various unit processes including disinfection, oxidation, coagulation, sedimentation, filtration, adsorption, gas transfer, and membrane filtration. The goal is to provide a theoretical understanding of various chemical and physical unit operations, with direct application of these operations to the design and operation of water and wastewater treatment systems. Students will use the concepts learned in this class to better understand the design and operation of engineered and natural aquatic systems.
Prerequisite(s): EN.575.601 Fluid Mechanics and EN.575.605 Principles of Water and Wastewater Treatment

EN.575.746 – Water and Wastewater Treatment Plant Design (3)
This course familiarizes students with appropriate design criteria and the design process for water and wastewater treatment plants. This includes design of treatment processes, cost estimates, and a working design team under project managers. Additional course requirements include oral presentations and writing engineering reports.
Prerequisite(s): EN.575.601 Fluid Mechanics and EN.575.605 Principles of Water and Wastewater Treatment and either EN.575.706 Biological Processes for Water and Wastewater Treatment or EN.575.745 Physical and Chemical Processes for Water and Wastewater Treatment and Wastewater Treatment

EN.575.749 – Water Quality of Rivers, Lakes, and Estuaries (3)
Sustainably managing aquatic environments for ecosystem and public health in a changing climate requires us to understand the combined effect of multiple physical, chemical, and biological processes. This class will equip students to apply their understanding of environmental engineering principles to real-world water quality issues using computer simulation models. The approaches covered are widely used in the US for TMDL studies and NPDES permitting under the clean water act. Emphasis will be placed on gaining insight by understanding fundamental assumptions and equations, and application to classical problems of oxygen demand and eutrophication. Advanced topics including pathogen and toxin dynamics will also be introduced.
Prerequisite(s): Differential equations

EN.575.761 – Measurement and Pseudo-measurement in the Environmental Arena (3)
In this course, students will be provided with the knowledge to critically investigate practical, theoretical, mathematical, philosophical, sociological, and legal aspects of measurement and pseudo-measurement in environmental science and related disciplines. Students will explore the theoretical and mathematical bases for quantification and trace the relationship between these bases and the expanding role of quantification and pseudo-quantification in environmental research, policy, and decision making. Three theories of measurement (traditional, representational, and operational) will be presented from historical, technical, and philosophical perspectives. Claims to quantification arising in several environmental contexts (such as river systems and hydrology) will be closely examined in light of these divergent measurement paradigms.

EN.575.801 – Independent Project in Environmental Engineering, Science, and Management (3)
This course provides students with an opportunity to carry out a significant project in the field of environmental engineering, science, technology, planning, or management as a part of their graduate program. The project is individually tailored and supervised under the direction of a faculty member and may involve conducting a semester-long research project, an in-depth literature review, a non-laboratory study, or application of a recent development in the field. The student may be required to participate in conferences relevant to the area of study. To enroll in this course, the student must be a graduate candidate in the Environmental Engineering, Science, and Management Program within the latter half of the degree requirements and must obtain the approval and support of a sponsoring faculty member in the Department of Environmental Health and Engineering. The proposal description and completed required forms must be submitted prior to registration for approval by the student's advisor and the program chair. A maximum of one independent project course may be applied toward the master's degree or post-master's certificate.

Courses in the Environmental Engineering and Science Program Area

EN.575.601 – Fluid Mechanics (3)
This course introduces the principles of continuity, momentum, and energy applied to fluid motion. Topics include hydrostatics; ideal-fluid flow; laminar flow; turbulent flow; form and surface resistance with applications to fluid measurement; and flow in conduits and channels, pumps, and turbines.

EN.575.615 – Ecology (3)
The course examines an introduction to the organization of individual organisms into populations, communities, and ecosystems and interactions between organisms, humans, and the environment. Topics include causation and prediction in ecology; evolution and natural selection; populations and competition; biodiversity, extinction, and conservation; the impact of forest fragmentation and deforestation on diversity, erosion and sedimentation; wetland ecology and restoration; succession, stability, and disturbance; eutrophication and the Chesapeake Bay; island biogeography; and global climate change. An independent project will be required regarding a field site visited by the student; the student will examine an ecological, conservation, or restoration event or issue about that site.

EN.575.619 – Principles of Toxicology, Risk Assessment, & Management (3)
Risk assessment and risk management have become central tools in continued efforts to improve public safety and the environment within the limited resources available. This course introduces the basic concepts of environmental risk assessment, relative risk analysis, and risk perception, including identifying and quantifying human health impacts and evaluating ecological risk. The course describes legislative and regulatory initiatives that are attempting to base decisions on risk assessment, along with the controversy that surrounds such approaches. It also addresses specific federal requirements for risk analysis by industry. The course discusses the realities of using risk assessments in risk management decisions, including the need to balance costs and benefits of risk reduction, issues of environmental equity, accounting for the uncertainties in risk estimates, effective risk communication, and acceptable risk.

EN.575.626 – Hydrogeology (3)
This course is an introduction to groundwater and geology and to the interactions between the two. It provides a basic understanding of geologic concepts and processes, focusing on understanding the formation and characteristics of water-bearing formations. The course also addresses the theory of groundwater flow, the hydrology of aquifers, well hydraulics, groundwater resource evaluation, and groundwater chemistry. The relationship between the geologic concepts/processes and the groundwater resource are discussed. Examples include a discussion of the influence of the geologic environment on the availability and movement of groundwater and on the fate and transport of groundwater contaminants. Geotechnical engineering problems associated with groundwater issues are also covered.

EN.575.629 – Modeling Contaminant Migration through Multimedia Systems (3)
This course addresses contamination that can affect many media as it migrates through the environment. Typically, contaminant sources occur in soil, from which the chemicals then migrate to air, surface water, and groundwater. Predicting the movement of contaminants through these media requires addressing the fate and transport processes that predominate in each medium and integrating the interactions between the media. The course presents the basic principles and numerical methods for simulation contaminant migration from soil into and through surface-water bodies, air, and

groundwater. The basic processes of fate and transport in the various media will be addressed: entrainment, adsorption, volatilization, chemical reactions such as degradation and photolysis, convection, and Gaussian dispersion and deposition. Selected public-domain numerical models will be used to simulate the fate and transport processes. Central to the course will be a project that integrates multimedia environmental modeling through a case study.

EN.575.643 – Chemistry of Aqueous Systems (3)
This course examines the chemical principles necessary to understand water quality and contaminant fate in natural and engineered aqueous systems. Quantitative problem-solving skills are emphasized. Specific topics include acid-base reactions, carbonate chemistry, oxidation-reduction reactions, and metal speciation. Case studies applying fundamental principles to important environmental phenomena (e.g., eutrophication of surface waters, drinking water treatment, soil/subsurface contamination, mobility of radioactive metals, ocean acidification, and geoengineering) are key components of this course.

EN.575.645 – Environmental Microbiology (3)
This course covers fundamental aspects of microbial physiology and microbial ecology. Specific areas of focus include energetics and yield, enzyme and growth kinetics, cell structure and physiology, metabolic and genetic regulation, microbial/ environmental interactions, and biogeochemical cycles. The goal of this course is to provide a basic understanding and appreciation of microbial processes that may be applicable to environmental biotechnology.

EN.575.704 – Applied Statistical Analysis and Design of Experiments for Environmental Applications (3)
This course introduces statistical analyses and techniques of experimental design appropriate for use in environmental applications. The methods taught in this course allow the experimenter to discriminate between real effects and experimental error in systems that are inherently noisy. Statistically designed experimental programs typically test many variables simultaneously and are very efficient tools for developing empirical mathematical models that accurately describe physical and chemical processes. They are readily applied to production plant, pilot plant, and laboratory systems. Topics covered include fundamental statistics; the statistical basis for recognizing real effects in noisy data; statistical tests and reference distributions; analysis of variance; construction, application, and analysis of factorial and fractional-factorial designs; screening designs; response surface and optimization methods; and applications to pilot plant and waste treatment operations. Particular emphasis is placed on analysis of variance, prediction intervals, and control charting for determining statistical significance as currently required by federal regulations for environmental monitoring.

EN.575.708 – Open Channel Hydraulics (3)
The course covers the application of the principles of fluid mechanics to flow in open channels. Topics include uniform flow, flow resistance, gradually varied flow, flow transitions, and unsteady flow. The course also addresses flow in irregular and compound channels, backwater and 2D flow modeling, and applications to channel design and stability.
Prerequisite(s): EN.575.601 Fluid Mechanics or an equivalent course in fluid flow or hydraulics.

EN.575.713 – Field Methods in Habitat Analysis and Wetland Delineation (3)
This course provides students with practical field experience in the collection and analysis of field data needed for wetland delineation, habitat restoration, and description of vegetation communities.

Among the course topics are sampling techniques for describing plant species distributions, abundance and diversity, including the quadrat and transect-based, point intercept, and plot-less methods; identification of common and dominant indicator plant species of wetlands and uplands; identification of hydric soils; and the use of soil, topographic and geologic maps and aerial photography in deriving a site description and site history. Emphasis is placed on wetland vegetation, delineation and restoration. While many of the field examples are centered in the Maryland and Washington, DC region, the format is designed so that the student performs field work in the state, country or region in which they would like to specialize.
Prerequisite(s): EN.575.615 Ecology.

EN.575.716 – Principles of Estuarine Environment: The Chesapeake Bay Science and Management (3)
The course examines the basic physical, chemical, and biological components of the Chesapeake Bay ecosystem and how they interrelate in both healthy and degraded states of an estuary. The course focuses on the tidal waters of the Chesapeake Bay and its tributaries. It also covers the relationships of the bay with the surrounding watershed, atmosphere, and ocean as well as relevance to other coastal systems. Particular emphasis is on to anthropogenic stresses such as nutrient and contaminant pollution, habitat modification, and harvest of fish and shellfish. The most current Chesapeake Bay management issues and policies being pursued at the federal, state, and local levels of government are discussed in depth, including their scientific foundation.

EN.575.717 – Hydrology (3)
This course introduces the fundamental physical principles that are necessary to understand the occurrence, distribution, and circulation of water near Earth's surface. Students will be introduced to the global hydrological cycle and the influence of climate, geology, and human activity. Students will study the processes of precipitation and evapotranspiration; surface water flow, floods, and storage in natural and artificial reservoirs; groundwater flow; and whole-cycle catchment hydrology. Although less emphasized, water quality and water resources management issues will be discussed, and case studies presented. Throughout the course, a quantitative approach is taken in which mathematical descriptions of hydrological phenomena will frequently be an objective. The course will also provide an introduction to hydrological data acquisition and analysis.
Prerequisite(s): EN.575.601 Fluid Mechanics or an equivalent course in fluid flow or hydraulics.

EN.575.727 – Environmental Monitoring and Sampling (3)
Environmental monitoring and sampling provides the information needed for assessments of compliance with environmental criteria and regulatory permits, and status/trends to evaluate effectiveness of regulatory controls. Students will prepare a Sampling and Analysis Plan (SAP) as a course project to support a site-specific field data collection study for environmental sampling of air, surface water, groundwater, and soils. An overview of historical/current environmental issues, including public health and environmental impacts, for air, surface water, groundwater, and soil, is presented. An overview of regulatory requirements of federal environmental statutes and assessments of effectiveness of the Clean Water Act, Clean Air Act, Safe Drinking Water Act, CERCLA, and RCRA is presented. The course describes pollutant sources and physical, chemical, biological processes that govern transport and fate of contaminants in air, surface water, groundwater, and soils. The course examines the principles, methods, and strategies for monitoring and sampling of air, surface water, groundwater, and soil. Sampling methods are presented for discrete sampling, automated data acquisition, and remote sensing for air, surface water, groundwater, and soils. SAP requirements for the course project will be presented, including key

elements of Quality Assurance Project Plans and Field Sampling Plans. The course presents selected concepts of environmental statistics; an overview of data sources available from EPA, USGS and other agencies for air, surface water, groundwater, and soils; and interpretation of environmental data sets with GIS/mapping, data analysis, and statistical methods to support decision-making, site characterization, and evaluation of status/trends. Students will research online opportunities for "virtual" field trips to observe field sampling methods for air, surface water, groundwater, and soils media.

EN.575.728 – Sediment Transport and River Mechanics (3)
This course examines the processes of sediment entrainment, transport, and deposition and the interaction of flow and transport in shaping river channels. Topics reviewed include boundary layer flow; physical properties of sediment; incipient, bedload, and suspended-load motion; bed forms; hydraulic roughness; velocity and stress fields in open channels; scour and deposition of bed material; bank erosion; and size, shape, platform, and migration of river channels. In addition, the course develops techniques of laboratory, theoretical, and numerical modeling and applies them to problems of channel design, restoration, and maintenance.
Prerequisite(s): EN.575.601 Fluid Mechanics or an equivalent course in fluid flow or hydraulics.

EN.575.730 – Geomorphic and Ecologic Foundations of Stream Restoration (3)
This course presents principles from hydrology, sedimentation engineering, geomorphology, and ecology relevant to the design and evaluation of stream restoration projects. A watershed context is emphasized in developing the background needed to assess different design approaches. After developing a common foundation in stream dynamics, the course considers trade-offs among restoration objectives, the merits of analog and predictive approaches, the role of uncertainty in restoration design, and metrics for assessing ecological recovery. The course includes online discussions, design exercises, and review papers and finishes with an assessment of a stream in students' geographic regions.

EN.575.744 – Environmental Chemistry (3)
This course focuses on the environmental behavior and fate of anthropogenic contaminants in aquatic environments. Students learn to predict contaminant properties influencing contaminant transfers between hydrophobic phases, air, water, sediments, and biota, based on a fundamental understanding of physico-chemical properties, intermolecular interactions, and basic thermodynamic principles. Mechanisms of important transformation reactions and techniques and quantitative models for predicting the environmental fate or human exposure potential of contaminants are discussed.

EN.575.763 – Nanotechnology and the Environment: Applications and Implications (3)
This course explores the positives and negatives of nanotechnology: the benefits to use in commercial and environmental applications, as well as considering nanoparticles as an emerging environmental contaminant. The course will analyze nanotechnology through an interdisciplinary outlook for a life-cycle analysis. This analysis will begin with synthesis, manufacturing, unintentional releases, and disposal. We will consider ecological consequences and public health implications of the use of nanotechnology. Students will learn the science behind nanotechnology and how nanoparticle characteristics impact transport in the environment, including human exposure assessment, and a discussion of current measurement tools. Policies regulating nanotechnology and risk assessment will be addressed.

EN.575.801 – Independent Project in Environmental Engineering, Science, and Management (3)
This course provides students with an opportunity to carry out a significant project in the field of environmental engineering, science, technology, planning, or management as a part of their graduate program. The project is individually tailored and supervised under the direction of a faculty member and may involve conducting a semester-long research project, an in-depth literature review, a non-laboratory study, or application of a recent development in the field. The student may be required to participate in conferences relevant to the area of study. To enroll in this course, the student must be a graduate candidate in the Environmental Engineering, Science, and Management Program within the latter half of the degree requirements and must obtain the approval and support of a sponsoring faculty member in the Department of Environmental Health and Engineering. The proposal description and completed required forms must be submitted prior to registration for approval by the student's advisor and the program chair. A maximum of one independent project course may be applied toward the master's degree or post-master's certificate.

Courses in the Environmental Planning and Management Program Area

EN.575.608 – Optimization Methods for Public Decision Making (3)
This course is an introduction to operations research as applied in the public sector. Public sector operation research involves the development and application of quantitative models and methods intended to help decision makers solve complex environmental and socio-economic problems. The course material is motivated by real-world problems and is presented in an environmental engineering-relevant context. Such problems include air pollution control, water resources management, transportation planning, scheduling, resource allocation, facility location, and biological conservation. Emphasis is placed on skill development in the definition of problems, the formulation of models, and the application of solution methodologies. Methodologies covered in this course include linear programming, integer programming, multi-objective optimization, and dynamic programming.

EN.575.611 – Economic Foundations for Public Decision Making (3)
The course examines intermediate-level price theory and surveys applications to public-sector decision making. Topics include demand, supply, behavior of the market, and introductory welfare economics. Applications include forecasting, cost-benefit analysis, engineering economics, and public sector pricing.

EN.575.628 – Business Law for Engineers (3)
This course introduces engineers to the basic legal principles they will encounter throughout their careers. Course discussions cover contracts (formation, performance, breach, and termination), corporations and partnerships, insurance, professional liability, risk management, environmental law, torts, property law, and evidence and dispute resolution. The course emphasizes those principles necessary to provide engineers with the ability to recognize issues that are likely to arise in the engineering profession and introduces them to the complexities and vagaries of the legal profession.

EN.575.635 – Environmental Law for Engineers & Scientists (3)
This course explores fundamental legal concepts relevant to environmental issues, including the relationship between statutes, regulations, and court decisions. Also included are various forms of enforcement used in environmental rules: command and control, liability, and information disclosure. Specific issues include criminal enforcement, a survey of environmental statutes,

regulations and case law, the purpose and misconceptions surrounding environmental audits and assessments, the concept of attorney-client privilege, unauthorized practice of law, and ethical conflicts between the attorney and engineer/scientist roles.

EN.575.637 – Environmental Impact Assessment (3)
This course examines principles, procedures, methods, and applications of environmental impact assessment. The goal of the course is to promote an understanding of how environmental impact assessment is conducted and used as a valuable tool in the engineering project management decision-making process. Topics include an overview of environmental impact assessment; selection of scientific, engineering, and socioeconomic factors in environmental impact assessment; identification of quantitative and qualitative environmental evaluation criteria; application of traditional and other techniques for assessing impacts of predicted changes in environmental quality; approaches for identifying, measuring, predicting, and mitigating environmental impacts; modeling techniques employed in environmental impact assessment; environmental standards and the environmental impact assessment process; and methodologies for incorporating environmental impact assessment into management decision-making. Students learn to prepare an environmental impact assessment, review and critically analyze an environmental impact statement, use mathematical models for environmental impact prediction, and apply environmental impact assessment as a tool in management decision-making. Case studies of environmental impact assessment for several types of engineering projects are employed.

EN.575.640 – Geographic Information Systems (GIS) and Remote Sensing for Environmental Applications (3)
Through lectures and laboratory exercises, this course illustrates the fundamental concepts of GIS and remote sensing technologies in the context of environmental engineering. Topics include the physical basis for remote sensing, remote sensing systems, digital image processing, data structures, database design, and spatial data analysis. The course is not intended to provide students with extensive training in particular image processing or GIS packages. However, hands-on computer laboratory sessions re-enforce critical concepts. Completion of a term project is required.

EN.575.707 – Environmental Compliance Management (3)
The course covers compliance with environmental laws and regulations by industry, small business, government facilities, and others. It includes legal responsibilities, environmental management systems, and practices such as audits and information systems and development of corporate policies and procedures that rise to the daunting challenge to harmonize the institution's primary goals with its environmental obligations. Several dimensions of environmental management are discussed: federal, state, and local regulation; scientific/technical factors; public relations and the press; and institutional objectives including economic competitiveness.

EN.575.710 – Financing Environmental Projects (3)
This course treats the financing of projects from two complementary perspectives: that of a government agency funding source, and that of an environmental utility (water, wastewater, solid waste) that needs funds for its project. It discusses grants, concessionary loans, market loans, and loan guaranties, along with their relative desirability and efficiency. Since grant funding is never available for all projects, the course deals extensively with borrowing/lending. It discusses strategies for maximizing utility income, including appropriate tariff structures and the reform of government subsidy policy from supply-based general subsidies to demand-based targeted subsidies. Operational strategies to maximize income are also discussed, such as techniques to improve billing and

collections, reduce losses, and reduce energy costs. Traditional cash flow analyses are used to determine debt service capabilities. Various project cost reduction strategies, such as staging and scaling, are introduced. Grants in the form of upfront project cost buy-downs vs. annual debt service subsidies are compared. Finally, several examples of project financings combining many of the elements introduced during the course are presented and analyzed.

EN.575.714 – Water Resources Management (3)
This multidisciplinary course examines the scientific, institutional, and analytical aspects of managing water quantity and quality. Students are provided a historical context that is useful for assessing current policy. The water cycle and basic hydrology are reviewed. The course surveys the laws and regulatory instruments for managing water quantity and quality, which operate across federal, state, and local levels of government. Funding issues associated with water resources management include operating and capital budgets, debt financing, the challenges of pricing, and the role of privatization. The course addresses the management of water supply and demand in the United States by economic sector and by in-stream and off-stream uses. This includes trends in water supply and demand, as well as modeling methods for water supply management. Fundamentals of flood and drought management are covered, with attention given to the context of global climate change and extreme events. The critical role of the public in water resource management decision making is addressed in the context of structured techniques involving economic analyses, multiobjective analyses, and collaborative decision making. Water quality-based management under the federal Clean Water Act includes the topics of water quality standards, water quality assessments, total maximum daily loads (TMDLs), and ensuing permit requirements. Regional ecological water resources management is addressed for the Susquehanna River and by contrasting the Chesapeake Bay case with other largescale cases.

EN.575.731 – Water Resources Planning (3)
The course will discuss the application and interrelationships among microeconomics, ecology, hydrology, and fields related to the planning and management of water systems. Topics will include flood control, navigation, hydroelectric power, water supply, environmental restoration, multi-objective planning, and urban water resource management. The course will demonstrate the process for planning a water resource project, including identifying the problems and opportunities, inventorying and forecasting conditions, formulating alternative plans, evaluating alternative plans, comparing alternative plans, and selecting a plan. Particular attention will be paid to the appropriate interdisciplinary approach to plan formulation.

EN.575.737 – Environmental Security with Applied Decision Analysis Tools (3)
This multi-disciplinary course examines current and emerging environmental security issues at multinational, national, and regional scales. These issues are approached from the perspective of decision-making for policy, planning, and management. The course begins with an overview and definitions of environmental security within the context of present global demographic patterns, use of natural resources, and climate change. The theory and principles of multi-criteria decision analysis (MCDA) are reviewed, using environmental security examples to illustrate concepts. Three MCDA methodologies are presented, including multi-attribute weighting, Analytic Hierarchy Process, and outranking, which are commonly used to assist decision makers. The MCDA approach is critiqued from the perspective of measurement theory and guidelines for MCDA use are

suggested. With both the social sciences and natural sciences providing a framework, several specific environmental security topics are covered in greater depth: energy; air quality; ecosystems and biodiversity; fresh water; agriculture and food; and sea level rise. Within these topics, students will develop MCDA models for particular policy, planning, and management problems under the guidance of the instructors. The course concludes by considering the prospects for environmental security and sustainability in the coming decades.

EN.575.747 – Environmental Project Management (3)
This course educates students on the key elements of an integrated approach to environmental project management, an endeavor that requires expertise in scientific, engineering, legal, public policy, and project management disciplines. Emphasis is placed on critical factors that are often unique to a major environmental project, such as the uncertainty surrounding scope definition for environmental cleanup projects and the evolving environmental regulatory environment. The students learn to develop environmental project plans, establish project organization and staffing, define management functions, develop time management approaches, resolve project conflicts, determine project effectiveness, and implement integrated project management techniques such as the Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM) as they relate to environmental project management, perform pricing and cost estimating, establish cost control, set priorities, and perform trade-off analyses. The course uses environmental project case studies to examine the integrated nature of environmental project management. Examples of topics to be covered in this case study format include environmental security projects, environmental technology deployment projects, privatization of governmental environmental projects, and pollution prevention/waste minimization projects.

EN.575.753 – Communication of Environmental Information and Stakeholder Engagement (3)
This course provides students with the skills for communicating scientific environmental data and sustainable engineering design to stakeholders, including scientists in different fields, policy decision makers, and the interested public. The course covers the importance of clear communication of complex scientific information for the development and acceptance of technologies, public policy, and community based environmental initiatives. The key stakeholders for environmental engineers, scientists, and managers are specified. Methods of engagement and designing key messages are defined for global, national, and local issues of student interest. Major types of communication media are covered, including written communication and graphics, online communications in short- and long-form new media, and interactive communications such as surveys and citizen science to involve stakeholders in the creation and analysis of big data and dispersed information. The emphasis of the course is from the point of view of an environmental professional (not a marketing professional) and developing an effective science-based communications portfolio to share complex scientific information with a broad range of interested parties.

EN.575.759 – Environmental Policy Analysis (3)
The course explores the process of analyzing environmental policies to ensure human health, that environmental needs are protected, and that the physical environment is preserved, protected, and restored, if necessary. Emphasis is placed on the need to evaluate and make decisions regarding environmental science, human health, sociopolitical, technological, legal, and economic considerations in a context of incomplete information and uncertain futures. Case studies and policies relating to various contemporary environmental issues, for example hazardous waste disposal, natural resource extraction and preservation of natural resources, are critiqued during the

semester. The course will lead students through the various steps of the policy analysis process. Students are expected to evaluate policy alternatives, develop evaluation criteria, and apply qualitative and quantitative methods to determine consequences, trade-offs, and potential synergies relating to these environmental issues. Students will then use these skills to create and execute an individual research project that analyzes an environmental policy relating to a specific issue of interest to them, evaluating potential responses to environmental management problems through analyzing the impacts of each policy alternative.

EN.575.801 – Independent Project (3)
This course provides students with an opportunity to carry out a significant project in the field of environmental engineering, science, technology, planning, or management as a part of their graduate program. The project is individually tailored and supervised under the direction of a faculty member and may involve conducting a semester-long research project, an in-depth literature review, a non-laboratory study, or application of a recent development in the field. The student may be required to participate in conferences relevant to the area of study. To enroll in this course, the student must be a graduate candidate in the Environmental Engineering, Science, and Management Program within the latter half of the degree requirements and must obtain the approval and support of a sponsoring faculty member in the Department of Environmental Health and Engineering. The proposal description and completed required forms must be submitted prior to registration for approval by the student's advisor and the program chair. A maximum of one independent project course may be applied toward the master's degree or post-master's certificate.

Appendix B
Climate, Energy, and Environmental Sustainability Faculty

Faculty Member	Highest Degree	Degree Field	Employer	Status at JHU	School Title	Classes Taught
Hedy Alavi	PhD	Civil Engineering	JHU Whiting School of Engineering	FT	Program Chair	575.604, 575.620, 575.742, 575.637
J. Hugh Ellis	PhD	Civil Engineering	JHU Whiting School of Engineering	FT	Lecturer	575.771
Ciaran Harman	PhD	Civil Engineering	JHU Whiting School of Engineering	FT	Lecturer	575.749
Thomas Jenkin	PhD	Physics	JHU Whiting School of Engineering	FT	Lecturer	575.732
Meghan Klasic	PhD	Geography	University of Minnesota	PT	Lecturer	575.711
Deborah Kopsick	PhD	Environmental Science and Policy	JHU Whiting School of Engineering	PT	Lecturer	575.736, 575.750
Ralph Lightner	PhD	Nuclear/Chemical Engineering	JHU Whiting School of Engineering	PT	Lecturer	575.733, 575.607
John Munro	PhD	Political Science	University of Maryland	PT	Lecturer	575.738
Gonzalo Pita	PhD	Building Vulnerability and Natural Disaster Risk Modeling	JHU Whiting School of Engineering	FT	Lecturer	575.623, 575.658
Harihar Rajaram	ScD	Civil Engineering - Hydrology and Water Resources	JHU Whiting School of Engineering	FT	Lecturer	575.715
Michael Robert	PhD	Civil and Environmental Engineering	JHU Whiting School of Engineering	PT	Lecturer	575.721, 575.722, 575.743, 575.629, 575.727
William Roper	PhD	Environmental Engineering	JHU Whiting School of Engineering	PT	Lecturer	575.723, 575.734, 575.640

APPENDIX C

Table 1: Program Resources

RESOURCES	2024-2025	2025-2026	2026-2027	2027-2028	2028-2029
1. Reallocated Funds	$0	$0	$0	$0	$0
2. Tuition/Fee Revenue (c + g below)	$207,484	$361,367	$528,681	$710,320	$907,237
a. Number of F/T Students	0	0	0	0	0
b. Annual Tuition/Fee Rate	NA	NA	NA	NA	NA
c. Total F/T Revenue (a x b)	$0	$0	$0	$0	$0
d. Number of P/T Student Enrollments	39	65	91	117	143
e. Credit Hour Rate	$1,773	$1,853	$1,937	$2,024	$2,115
f. Credits Per Course	3	3	3	3	3
g. Total P/T Revenue (d x e x f)	$207,484	$361,367	$528,681	$710,320	$907,237
3. Grants, Contracts & Other Ext Sources	$0	$0	$0	$0	$0
4. Other Sources	$0	$0	$0	$0	$0
TOTAL (Add 1 – 4)	**$207,484**	**$361,367**	**$528,681**	**$710,320**	**$907,237**

Resources Narrative

1. Reallocated Funds: The proposed program will be funded by tuition revenue, and will make no use of reallocated funds.
2. Tuition and Fee Revenue: The enrollment projections in Table 1 are a reasonable estimate based on growth of other JHU-EP master's degree programs. The Master of Science in Climate, Energy, and Environmental Sustainability is a part-time degree program, so no full-time students are expected. JHU-EP students take, on average, three 3-credit courses per year, which is reflected in the "Annual Credit Hour Rate."
3. Grants and Contracts: No grants or contacts are required for the successful implementation of the program.
4. Other Sources: The program does not expect any funding from other sources.

Table 2: Program Expenditures

EXPENDITURES	**2024-2025**	**2025-2026**	**2026-2027**	**2027-2028**	**2028-2029**
1. Faculty (b + c below)	$44,517	$79,739	$91,504	$129,052	$155,141
a. # FTE	0.7	1.2	1.3	1.8	2.2
b. Total Salary	$41,219	$73,832	$84,726	$119,493	$143,649
c. Total Benefits	$3,298	$5,907	$6,778	$9,559	$11,492
2. Admin. Staff (b + c below)	$25,915	$26,588	$27,279	$27,988	$28,717
a. # FTE	0.75	0.75	0.75	0.75	1.75
b. Total Salary	$25,140	$25,797	$26,472	$27,166	$27,878
c. Total Benefits	$775	$791	$807	$823	$839
3. Support Staff (b+c below)	$11,661	$23,789	$12,132	$24,750	$25,245
a. # FTE	0.125	0.25	0.125	0.25	0.25
b. Total Salary	$8,670	$17,687	$9,020	$18,401	$18,769
c. Total Benefits	$2,991	$6,102	$3,112	$6,348	$6,475
4. Equipment	$0	$0	$0	$0	$0
5. Library	$0	$0	$0	$0	$0
6. New or Renovated Space	$0	$0	$0	$0	$0
7. Other Expenses	$56,238	$96,542	$139,213	$184,358	$232,087
TOTAL (Add 1 – 7)	**$138,331**	**$226,657**	**$270,128**	**$366,149**	**$441,189**

Expenditures Narrative

1. Faculty: The Engineering for Professionals lecturers are paid $9,857 (for 2023-2024) per course taught and $10,840 per course developed. These were used as base rates. For years 1 – 5, an additional 2% was added to the salary rate. The fringe rate is estimated at 8%.
2. Administrative Staff: Includes salary for Program Chair and advisors.
3. Support Staff: Includes pro-rated salaries for F/T Instructional Designers, Instructional Technologists and Multimedia Technicians to assist in developing online courses.
4. Equipment: No direct equipment costs are identified.
5. Library: Existing library facilities are sufficient to meet the needs of the program.
6. New or Renovated Space: No new or renovated space will be needed.
7. Other Expenses: Indirect program costs plus direct expenses associated with the Program

Chair (conferences, travel, task support) are provided here.