Syllabus

ENV5619
Principles of Sustainable Engineering Design

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ENV5619
PRINCIPLES OF SUSTAINABLE ENGINEERING DESIGN

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OVERVIEW

Why take this course? Here is my course "BHAG," the acronym for what management authors Jim Collins and Jerry Porras called a Big Hairy Audacious Goal.[1]

> *When you complete this course, you will be able to discuss the issues of sustainability and climate change confidently with your clients, customers, bosses and friends, and identify opportunities and risks they never imagined they had.*

This course is designed to help students navigate through the complex and often confusing issues of sustainability and their relationship to engineering design. Aimed at upper-level undergraduate and graduate students, the course covers a wide range of subjects, including sustainable and unsustainable systems, assessment of ecosystem conditions, the impacts of climate change, the sustainability of nations, the business case for sustainability, sustainable engineering tools and techniques, resilient and sustainable cities, and prospects for a sustainable future. Critical issues of sustainability and its effects on civil infrastructure are explained. Emphasis is given to climate change and how that product of human activity is altering the fundamental assumptions of civil infrastructure design and operation. Tools and methodologies for assessing the effects and impacts, and delivering safe, reliable civil infrastructure projects are also offered.

Students completing this course will gain new perspectives on engineering design for sustainability, and how industry and government organizations are incorporating sustainability principles and practices into their operations. Students will also learn why these organizations believe that taking these actions makes good economic and business sense.

This course is tailored to give students considerable flexibility in meeting the course requirements. All the lecture modules (75, averaging approximately 30 minutes each) are pre-recorded and available on the first day of the semester. A list and description

[1] James C. Collins and Jerry I. Porras, *Built to Last: Successful Habits of Visionary Companies*, HarperCollins Publishers, New York (1994).

of the lecture modules is provided at the end of this syllabus. Students can view these modules at any time, and at a pace that can adjust to their schedules. To meet course requirements and to hone their writing skills, students prepare three, 5000-word papers on sustainability-related topics. Paper topics are student-selected from a list of over 50 pre-described topics. Alternatively, a student can propose topics that meet his/her own interests and/or field of work or study. Grades for the course will be based primarily (75%) on the three student papers. The remainder of the grade will be based on correct answers to multiple-choice questions about the material covered in the lecture modules.

BACKGROUND

The notion that the society's form of economic development was not sustainable emerged in the late 1980s. Noting the harmful effects on resources, society and the environment, the United Nation's Brundtland Commission called for future economic development to be *sustainable*, i.e., "meet the needs of the present without compromising the ability of future generations to meet their own needs." The Commission noted that the environment, economy and society were inextricably connected, that is, damages to the environment and its ecological systems also damaged the economy and societal well-being.

Today, we are experiencing the harmful effects of literally centuries of unsustainable behavior. Resources, once thought of as effectively inexhaustible, are now seen as finite and increasingly scarce. Ecological systems, once thought of as essentially boundless, robust and self-repairing, are now seen as limited and already damaged by human activity.

Importantly, damage to climate-regulating ecological systems, caused by increased atmospheric concentrations of greenhouse gases, has resulted in a changing climate. That change is altering significantly the environmental conditions under which civil infrastructure is expected to operate. Consequently, long-held engineering design assumptions such as expected ambient temperatures, sea levels, storm intensity, and the extent of droughts and heat waves are no longer reliable. Unknowingly, today's engineers are planning, designing and constructing infrastructure projects that will not be able to cope with future environmental operating conditions. Infrastructure projects designed to be long-lived are especially vulnerable to these changing conditions.

Owners and overseers of this nation's infrastructure are responding to these changes in important ways. The U.S. Department of Transportation has produced extensive guidance on assessing infrastructure vulnerability to climate change. The U.S. Environmental Protection Agency has published tools for developing climate resilience for water and wastewater management systems. The UK's Heathrow Airport has created a framework for assessing operational risk and formulating an effective response to climate change. These are a few examples of how decision-makers are expecting infrastructure projects to be planned, designed and delivered now and in the future. Today's engineers and practitioners need to meet these expectations to be successful.

In this course, improving the sustainable performance of infrastructure is not treated as how to insert so-called “green” add-ons to traditional designs. Instead, sustainable engineering is treated as the management of change. Conditions of non-sustainability are, in effect, creating a “new normal” in terms of operating conditions and performance requirements. Traditional assumptions about averages, variances and plausible extremes for design variables are no longer reliable. This course will identify and assess these areas of change and offer a corresponding engineering design approaches to effectively manage this change.

The effects and consequences of non-sustainable behavior on nations (developed, developing, and underdeveloped) are also presented along with their respective challenges and considerations in engineering design. How industry and government sectors have responded will also be addressed, as these institutions have and continue to drive changes in engineering design and performance criteria associates with sustainability. Their responses and accomplishments will be presented in a business context, showing how these changes relate to competitiveness and improved economic performance.

Tools such as sustainability metrics, life cycle assessment, sustainability auditing and carbon footprinting will be demonstrated. Finally, new techniques for delivering projects that maximize contributions to sustainable performance while accounting for changing environmental operating conditions will be introduced.

OBJECTIVES OF THIS COURSE:

- Introduce the concepts of sustainable development and sustainability in its proper form, separating them from the popularized and largely inaccurate notions about being “green” to ones that have a scientific and engineering basis.
- Convey an understanding of what is really required to achieve conditions sustainability through principles such as The Natural Step, and Herman Daly’s thermodynamic definitions of sustainability. Introduce the Five Capitals model as a coherent way of thinking about sustainability.
- Learn about the trends and forces shaping our world instigated by our non-sustainable economic model for growth and development. Offer a view the salient events in the development of our current concepts of sustainability.
- Learn about the causes, effects, consequences and controversies surrounding global climate change. Understand the mechanisms that are causing global warming. Learn about approaches for addressing climate change: robustness, resilience, redundancy and adaptation. Learn about some of the solutions being proposed, including the ones categorized as geoengineering.
- See the effects of unsustainable development on the developed, developing and underdeveloped nations and learn about the engineering challenges specific to each.
- Characterize the trends and drivers that are shaping industry and governmental responses to the consequences of non-sustainability.

- Learn about the degree to which various industry and government sectors, cities and communities understand the issues and consequences of non-sustainable behavior and how they are responding. Learn how these organizations are incorporating sustainability principles and practices into their operations.
- Define and explore the principles of biomimicry, industrial ecology and by-product synergy and see how they are being applied.
- Survey the current laws, regulations and standards that are being put in place to address the various dimensions of sustainability.
- Learn and place in context the various systems for measuring sustainable performance.
- Gain experience in using the various tools and techniques available for designing and implementing energy conservation measures, conducting life cycle assessments, calculating carbon footprints, and more.
- Learn how to design and deliver projects that are climate-safe and contribute to conditions of sustainability.

WHAT YOU ARE EXPECTED TO KNOW COMING INTO THIS CLASS

A modest understanding of the concepts and issues surrounding sustainable development will be helpful. I will present the facts and figures that make a case that our current model of economic development is not sustainable in its current form. Many charts and graphs of varying complexities will be used to illustrate these points, so basic math skills are required.

I will also be presenting a business case for sustainable development through discussions of how incorporating sustainability policies and practices can improve performance, reduce costs and otherwise make organizations more competitive. Therefore, some understanding of how business and governmental organizations operate will be helpful.

If you are unsure if your qualifications will enable you to be successful in this course, feel free to contact me to discuss.

Mobile: (970) 819-2188

Email: wawallace2@ufl.edu or bill.wallace@wallacefutures.com

TEXTBOOK FOR THE CLASS

There is no textbook for this class. Instead, I will supply students with a number of publications that contain relevant and current information about the subject. Some of these will be required reading assignments for the course. Others will be references that I thought students should be aware of and could use as general references.

COURSE DELIVERY

The course will be delivered as a series of **75 pre-recorded lectures averaging approximately 30 minutes each**. They are available on the University's E-Learning website, through the Canvas System. I intend to make all lectures are available for viewing at the beginning of the semester. If they are not all available on the first day, it is because I am in the process of updating some of the lectures. I will let you know if that is the case.

Students should plan to view the course lectures at a pace that will enable them to complete the course within the semester timeframe.

COURSE FORMAT

I have created handouts of the lecture presentations in "PDF" format so that students can print out the handouts to take notes without having to copy information from the slides. Yes, this means that paper will be used. However, your negative impacts on the environment will be negligible compared to the learning benefits. If you find that you still have pangs of guilt after printing the handouts, feel free to plant one or more trees as compensation.

These files will be available on the ENV5619 E-Learning site on Canvas. If you use these handouts, make sure you're using the latest version of Adobe Reader or a suitable "PDF" file reader.

INSTRUCTOR AVAILABILITY

If you have questions or need help regarding the course or any of the assignments, please contact me. Email is preferable, but telephone calls are also welcome. Students are encouraged to ask questions at any time. If you have questions or just want to discuss the course, please call (8 AM – 5 PM Pacific Time) or send me an email. Mobile: (970) 819-2188. Email: wawallace2@ufl.edu.

EXAMS

There are no comprehensive examinations for this course. Final grades will be based on the delivery and achievements on three papers (75%) and the course module quizzes (25%).

QUIZZES

The quizzes consist of one or more multiple choice questions for each module, based on the content of that module. The purpose of these quiz questions is to give assurance that students are progressing through the course. There are no trick questions on these quizzes. Students who viewed the video module and followed the presentation handout should be able to answer the question easily.

PAPERS

Students are required to prepare three (3) research papers on subjects selected by the student from a list of paper topics. The topics are designed to test the student's grasp of the subject matter and to expand and extend that learning into related areas. The **Paper Topics List** is found in the Syllabus section of the ENV5619 E-Learning site. A list and description of topics for these papers is provided on the course website. There are over 50 topics covering a wide range of sustainability issues.

If a student has a specific interest in a particular sustainability topic, which relates to the course material but does not appear on the topic list, he/she can create his/her own topic and submit a short description of that topic to me for approval. Students should not begin work on their self-designed topics without my approval, since the absence of my approval disqualifies the student's paper from being considered in his/her course grade.

Please note that I am **not** expecting the papers to be the sort of work product that one would submit to an academic journal. In this course, an "A" graded paper would be a paper that is more or less ready for submission to a popular professional or trade journal, or a report that you would submit to your bosses or clients, or discuss with your colleagues.

Paper requirements and grading criteria

Guidance for preparing papers are presented in a document called **Paper Preparation Guidelines** located on the course E-Learning website. This document contains a detailed description of what I expect to see in your project report submissions and criteria for how they will be graded. Each paper should be at least 5000 words, not including references. Papers containing less than 5000 words will be downgraded accordingly. I will also downgrade papers that are submitted after the published due date, approximately 1 point per day. Papers submitted more than one week after the published due date will not be graded and will count as a zero in the student's overall course grade.

Paper Grading Criteria

Papers will be graded based on the quality of the content and timeliness of delivery. The due dates for these papers are listed in the class schedule. General criteria for paper grades are presented below.

In order to grade these papers fairly and consistently, I have developed a grading rubric based on writing guidelines and scoring tools used by various colleges and universities to evaluate student writings. This is a methodology that enables me to assign point scores to various aspects of your paper: understanding and analysis, development and support, organization and presentation, and writing mechanics. The scoring also takes into account the basic requirements: timely delivery on or before the due date, and word count, i.e., 5000 words or more.

The rubric is available on the course e-learning website. In addition, I have included several articles and links that offer useful guidance on basic and technical writing.

COURSE GRADING

The final grade will be determined by an absolute method of grading to allow you to obtain a grade based on your individual performance without having to compete with one other. Under this scheme, it is possible for the whole class to get an A grade or, in the extreme case, for the whole class to get an E grade. I, of course, hope that you will work hard to earn an A.

DUES DATES FOR HOMEWORK AND PAPERS

All homework assignments and reports are due on or before the date and time specified in the Assignments section in the e-Learning system.

Grade	Criteria
A	Researched the topic extensively. Paper is well organized and written, as well as interesting and thought provoking. New knowledge and ideas offered. More-or-less ready for submission to a popular trade journal or presented at a meeting or conference. A few spelling or grammatical errors. *A+ (100-97) A (96-93) A- (92-90)*
B	Got the work done and met the specifications for the report. Good writing. Readable and somewhat interesting. Content is reasonably convincing, backed up by good references. Organization of the paper could use some improvement. Hard to follow the logic. Minor spelling and grammatical errors. Does not meet the 5000-word minimum. *B+ (89-86) B (85-82) B- (81-78)*
C	Wrote on the topic specified but missed the specifications for the paper. Barely sufficient research to support the arguments and conclusions. Writing style is awkward and hard to follow. Organizationally OK but frequently hard to determine what points are being made. Arguments are weak. Proof is slim to none. Some spelling and grammatical errors. Does not meet the 5000-word minimum. *C+ (77-74) C (73-70) C- (69-66)*
D	What is written is generally not on point. Hard to determine what the person is writing about. Content is marginal. Mostly stream-of-consciousness writing. Not well researched. Does not meet the 5000-word minimum. Many spelling and grammatical errors. *D+ (65-62) D (61-58) D- (57-56)*
E	Missed the point of the topic. Content has multiple inaccuracies. Statements not supported. Organization of the report is hard to follow. Conclusions don't follow the content. Poorly edited. Does not meet the 5000-word minimum. Spelling and grammatical errors abound. *E (≤ 55)*

ACADEMIC HONESTY

All students are expected to exhibit academic honesty and abide by the University's Honor Code. All papers must represent a student's own individual work unless otherwise directed by the instructor. Plagiarism in writing assignments is not acceptable and violates the University's Honor Code.

Please note that the University has provided me with software that does a very good job in uncovering instances of plagiarism. I have used the software in previous courses and have penalized students upon discovery that they had copied the work of others without proper citation.

DIVERSITY STATEMENT

The Herbert Wertheim College of Engineering (HWCOE) values a diverse and inclusive community. It is integral to success in every area of our college. Therefore, the College is committed to non-discrimination with respect to all areas of human differences, including but not limited to national and ethnic origin, race, age, sex, sexual orientation, gender identity and expression, beliefs and opinions, religion and faiths, culture, socio-economic background, level of physical or mental ability, and veteran's status. This commitment applies in all areas–to students, faculty, and staff and intends to reflect the College's belief that educational and employment decisions and access to University activities should be based on an individual's abilities and qualifications.

The HWCOE values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. We aspire to educate students to become future leaders capable of creating diverse and inclusive work cultures wherever their careers may take them.

STUDENT EVALUATIONS

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at https://gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via https://ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students at https://gatorevals.aa.ufl.edu/public-results/.

Course Content

<table>
<tr><td colspan="3">M1: UNDERSTANDING SUSTAINABLE DEVELOPMENT
In this first section I will introduce the course and describe the issues and challenges associated with sustainable development in the built environment: the roads, bridges, buildings, dams, water and wastewater treatment plants, and more. I will also describe how I set up the course, how I intend to run it, and how you can contact me for help, to discuss course content or if you just want to chat.
This first section offers answers to seven important questions regarding sustainability:
1. What is natural capital?
2. How does natural capital contribute to human development and well-being?
3. How did we get to this point in human development and well-being?
4. Is our approach to development sustainable, and if not, why not?
5. What are the consequences of unsustainable development?
6. What are we doing about unsustainable development?
7. What will it take to become a sustainable society?</td></tr>
<tr><td>1</td><td>M1.1</td><td>Designing Civil Infrastructure for the New Normal
What's past is no longer prologue!
Quick course summary. Let's begin with a story: Mr. Hirose and the Tokyo Subways. New and unanticipated problems in urban infrastructure. Stories closer to home and around the world.   Two "No more!" moments. What's happening: human activity is changing the climate. Burning fossil fuels for heat and energy is damaging the Earth's climate-regulating systems. What needs to happen: strengthen infrastructure, add resiliency, switch to low- or no-carbon energy. Is there hope? What this course is about and what it's not about. A Big, Hairy, Audacious Goal (B.H.A.G.).</td></tr>
<tr><td>2</td><td>M1.2</td><td>Course Organization and Content
What this course contains and how it will be delivered
Course outline and content summary. How the course will be run. Access to the course instructor (me). How to get the most out of this course. How to be successful in this course. Stories from the built environment.</td></tr>
<tr><td>3</td><td>M1.3</td><td>What Is Sustainable Development?
And why should you care?
Explaining sustainable development: my story. Origins of the concept. The Brundtland Commission: definition of sustainable development and key findings. Questions, concerns and interpretations. Linking the economy, the environment and society: multiple views. Visualizing what sustainable development means in terms of personal financial capital. Scale-up to natural capital. Is our form of economic development sustainable? Seven key questions. Answers to follow.</td></tr>
<tr><td>4</td><td>M1.4</td><td>Natural Capital, Human Development and Well-Being
How does natural capital contribute?
Sustainability on a planetary scale. Is our development sustainable? Are we, as a society, sustainable? How can we make this determination? Seven questions. Answering questions 1 and 2: (1) What is natural capital? and (2) How does natural capital contribute to human development and well-being? Abiotic and biotic systems and resources. Ecosystem resources and service flows. Example: earthworm biomass delivering multiple ecosystem services.</td></tr>
<tr><td>5</td><td>M1.5</td><td>How Did We Get Here?
How did we get to this point in human development and well-being?
Answering question #3: How did we get to this point in human development and well-being? Human ingenuity! We created new forms of capital. The Five Capitals model and examples. Application to human development and well-being. Human well-being in the Middle Ages. An example of 15th century medicine. Slow progress until the Industrial Revolution. Many benefits but also problems. How long can we keep this up?</td></tr>
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<tr><td>6</td><td>M1.6</td><td>Is Our Approach to Development Sustainable?
If not, why not?
Answering question #4: Is our approach to development sustainable, and if not, why not? What do need to know to figure out if our approach to development is sustainable? What tools do we have? Measuring our Ecological Footprint: ecological resources available vs. consumed. Measuring human well-being: The Human Development Index. Comparing the sustainability of nations: The Sustainability Quadrant. How well is human ingenuity being applied? What about the U.S.? Civil infrastructure and its contribution to the U.S. Ecological Footprint.</td></tr>
<tr><td>7</td><td>M1.7</td><td>What Are the Consequences of Unsustainable Development?
What happens when non-stationarity becomes the new normal?
Answer to question #5: What are the consequences of unsustainable development? How well are we managing natural capital? Findings of the Millennium Ecosystem Assessment (MA). Old Earth and new Eaarth. Consequences to civil infrastructure and engineering. Changes in ambient temperature in the northern hemisphere. Stationarity vs. non-stationarity. Non-stationarity and its impact on civil infrastructure design. What happens when non-stationarity becomes the new normal?</td></tr>
<tr><td>8</td><td>M1.8</td><td>What Are We Doing About Our Unsustainable Development?
Is it enough? If not, what's holding us back?
Answer to question #6: What are we doing about unsustainable development? Not very much! History of actions by nations to make our development sustainable. The Sustainability Quadrant and the trajectories of nations. Low-, middle- and high-income nations and their actions. What is the world doing about climate change? What needs to be done? What's holding us back? The Tragedy of the Commons. The Tragedy of the Horizon. Examples.</td></tr>
<tr><td>9</td><td>M1.9</td><td>What Will It Take to Become a Sustainable Society?
Making huge cuts in greenhouse gas emissions is the essential first step
Answer to question #7: What Will It Take to Become a Sustainable Society? The World Business Council for Sustainable Development's Roadmap to 2050: a business-driven approach toward sustainability. "Must Haves" by 2020. What needs to be done during the "Turbulent Teens." What has been accomplished? Climate change is driving the bus! Projected climate change impacts: various emissions scenarios. Is there hope? What progress is being made by the public and private sectors? New warnings from the Intergovernmental Panel on Climate Change (IPCC).</td></tr>
<tr><td colspan="3">M2: ASSESSING CURRENT CONDITIONS
This section begins with a presentation of some basic concepts in sustainability, including types of resources: biotic, abiotic, renewable, non-renewable. Also covered are several ways of framing the issues of sustainability in the built environment: ecological carrying capacity, eco-efficiency vs. eco-effectiveness, and The Natural Step. A model for visualizing sustainable and unsustainable systems is also provided. The discussions then shift to assessments of the current condition of our renewable and non-renewable resources, ecosystem services and critical materials.</td></tr>
<tr><td>10</td><td>M2.1</td><td>Basic Concepts in Sustainability
Understanding the issues and the terminology
Definitions. Types of resources: biotic, abiotic, renewable, non-renewable. Growth vs. development. Carrying capacity. Herman Daly's ecological definition of sustainability. Eco-efficiency vs. eco-effectiveness. Cradle to cradle design. Technical and biological metabolisms. The Natural Step: the four system conditions.</td></tr>
<tr><td>11</td><td>M2.2</td><td>The Millennium Ecosystem Assessment
The state of ecosystem services
Assessing the impacts of non-sustainability. The structure of ecosystem services. The Millennium Ecosystem Assessment findings. The relevance of ecosystem conditions to infrastructure. Deteriorating infrastructure and its consequences. "We're building 2050 today!" Are we getting the message across?</td></tr>
<tr><td>12</td><td>M2.3</td><td>A Brief History of Oil
A harbinger of things to come?
The discovery of oil. Birth of the modern oil industry. Oil production and consumption. Oil supply as a strategic issue. Other energy sources. Climbing the "heat ladder". New technologies. Is energy the tip of the iceberg? Other pending resource scarcities.</td></tr>
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<tr><td>13</td><td>M2.4</td><td>Is Water the Next Oil?
Setting the scale. Defining the issues.
Understanding water resources. The water cycle. Water distribution and movement. Global water footprint. Global water scarcity: physical and economic. Water issues for the U.S. Status of U.S. water infrastructure: the problems and the range of responses.</td></tr>
<tr><td>14</td><td>M2.5</td><td>Non-Renewable Resources
Once they're gone, they're gone!
Definition of non-renewable resources. Demand, regulatory trends, supply risks, prospects. Civil infrastructure focus: minerals and metals, construction materials, coal, oil and gas.</td></tr>
<tr><td>15</td><td>M2.6</td><td>Critical Materials
Materials needs, availability, supply risk and prospects for substitution
What are critical materials? History: ammonia as a critical material. Technology saves the day! Rare earth elements: Japan vs. China. Assessing the criticality of materials: clean energy technologies, national defense. Critical material strategies.</td></tr>
<tr><td colspan="3">M3: SUSTAINABILITY: THE STATE OF NATIONS
This section summarizes the state of the world's nations, expanding upon the discussions in Module M1.6 and M1.7.
M3.1 Sustainability and the Developed Nations: Not living within our means…and loving it!
M3.2 Sustainability in the Developing Nations: Economic growth is what matters!
M3.3 Sustainability in the Underdeveloped Nations: Survival!
The last module in this section, M3.4 Climate Change Is Simple…And Scary!, is a segue to the next section: Climate Change: The State of Play</td></tr>
<tr><td>16</td><td>M3.1</td><td>Sustainability in the Developed Nations
Not living within our means…and loving it!
The world we live in: characteristics of nations by level of development. Situation for the developed nations. Trends and drivers. Engineering needs. Pathway choices and sustainable design challenges. The Consumption-Land Use Matrix.</td></tr>
<tr><td>17</td><td>M3.2</td><td>Sustainability in the Developing Nations
Economic growth is what matters
Situation for the developing nations. Trends and drivers. Engineering needs. Pathway choices and sustainable design challenges. Response of the developing nations.</td></tr>
<tr><td>18</td><td>M3.3</td><td>Sustainability in the Underdeveloped Nations
Survival!
Situation for the underdeveloped nations. Trends and drivers. Engineering needs. Pathway choices and sustainable design challenges. Actions to assist: 2015 – Millennium Development Goals. 2030 – Global Goals for Sustainable Development.</td></tr>
<tr><td>19</td><td>M3.4</td><td>Climate Change is Simple…And Scary!
What happens if we continue on our "business as usual" carbon emissions course?
Dave Roberts explains climate change and its consequences.</td></tr>
<tr><td colspan="3">M4: INFRASTRUCTURE DESIGN FOR NON-STATIONARITY
This section describes the greenhouse effect and its relationship to the Earth's environmental conditions. How has our scientific understanding of the climate has evolved and what we know and don't know about the climate today? The effects of increasing atmospheric concentrations of carbon dioxide and other greenhouse gases on environmental conditions. What happens if greenhouse gas concentrations continue to increase? Ecological and regional impacts. Scenarios of future environmental conditions in a warming world. Implications to civil infrastructure design and operations. Approaches to climate change mitigation and adaptation. The promise and perils of geoengineering.</td></tr>
<tr><td>20</td><td>M4.1</td><td>Climate Regulating Ecosystem Services
The greenhouse effect
Earth's atmosphere. The greenhouse effect. Maintaining a stable climate. The Earth's carbon balance. Carbon dioxide concentrations, temperatures throughout history. Risks of a warming planet. Making the risks real. Thinking about risks at the scale of the built environment.</td></tr>
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21	M4.2	**History of Climate Science** ***Development of climate science and our understanding of global climate change*** How our understanding of climate change evolved, 1820 to the present. Role of carbon dioxide in warming the atmosphere. Milestones in climate science. Milestones in society's response to climate change.
22	M4.3	**Climate Change: What We Know and What We Don't Know.** ***What the climate scientists are telling us*** Framing the climate change issue. What we know and don't know about climate change. The development of the climate models. Climate change and its effects. How much is human caused?
23	M4.4	**The Ecological Impacts of Climate Change** ***Global changes. Regional and local impacts*** Ecological impacts of climate change. Regional impacts. Range shifts. Timing of biological activity. Arctic impacts. The global climate change controversy. (Hint: there is no controversy!)
24	M4.5	**Regional Impacts of a Changing Climate** ***Regional and temporal impacts on the U.S*** Definitions of risk and its components: hazards, exposures, vulnerabilities, risks. The regional and temporal impacts of a changing climate: continental U.S., Alaska and the Pacific Islands.
25	M4.7	**Climate Change Mitigation** ***Taking on the causes of climate change*** Our climate choices. Mitigation vs. adaptation. Key mitigation technologies by sector. Global greenhouse gas emissions mitigation cost curve. Mitigation through carbon capture, storage and use. Carbon sequestration.
26	M4.8	**Climate Change Adaptation** ***Accommodating changes in environmental operating conditions*** Climate change adaptation framework. Dealing with non-stationarity. Climate change adaptation strategies: protect, retreat, accommodate. Industry sector examples. U.S. adaptive capacity.
27	M4.9	**Climate Change Mitigation Through Geoengineering** ***Can technology save the day?*** What is geoengineering (a.k.a. climate engineering or climate intervention)? What are the points of intervention? What are the possibilities? Geoengineering concepts. The promise and perils of geoengineering (climate engineering). Climate engineering "Plan B." Evaluation of geoengineering (climate intervention) techniques by the National Research Council.
M5: INFRASTRUCTURE DESIGN FOR NON-STATIONARITY This section presents an approach for designing, constructing and operating civil infrastructure assets and systems under conditions of non-stationarity. Expectations of stakeholders for civil infrastructure performance. Current approaches to civil infrastructure design, assuming that environmental conditions are statistically constant. Climate stressors and their impacts. Climate variable attributes. Non-stationarity and its consequences to civil infrastructure. New sources of climate stressors. Deep uncertainty in future climate conditions. Decision-making under deep uncertainty: five methods for handling.		
28	M5.1	**Infrastructure Design Under the Assumption of Stationarity** ***The good old days: living and working in the "sweetest of sweet spots."*** Civil infrastructure: stakeholder expectations. Climate stressors and their impact on infrastructure. Environmental parameters (variables) and their probability distributions. A general design model for environmental parameters. Source of additional stressors. Range of values. Modes of failure.
29	M5.2	**Non-Stationarity and Its Consequences in Civil infrastructure Design** ***Climate variables are changing, and we don't know the full effects*** The effects of climate change and non-stationarity on civil infrastructure design. The causes: produced capital and its effects on ecosystem services. New sources of climate stressors. Examination of climate stressors and their effects. Examples. Introduction to deep uncertainty.

30	M5.3	**Infrastructure Planning and Design Under Conditions of Deep Uncertainty: a Summary** ***Dealing with highly uncertain outcomes: climate, non-stationarity, and otherwise*** Civil infrastructure and deep uncertainty. The third ape's problem. Our history of making economic forecasts: not good! Extent of uncertainty in infrastructure design. Example of a deep uncertainty problem. The five levels of uncertainty. Five methods for handling deep uncertainty in infrastructure design derived from the book, V. A. W. J. Marchau et al. (eds.), *Decision Making under Deep Uncertainty*.
31	M5.4	**Methods for Handling Deep Uncertainty, Part 1** ***Robust Decisionmaking (RDM) and Dynamic Adaptive Planning (DAP)*** Description of two methods for handling deep uncertainty: Robust Decisionmaking (RDM) and Dynamic Adaptive Planning (DAP). Case examples: Colorado River Basin water supply, Port expansion in Barranquilla, Columbia.
32	M5.5	**Methods for Handling Deep Uncertainty, Part 2** ***Dynamic Adaptive Policy Planning (DAPP), Info-Gap Decision Theory (IG) and Engineering Options Analysis (EOA)*** Description of three methods for handling deep uncertainty: Dynamic Adaptive Policy Planning (DAPP), Info-Gap Decision Theory (IG) and Engineering Options Analysis (EOA). Case examples: Water resource policies for climate change in southern Portugal, Water supply (general), Replacement of the Netherlands IJmuiden pumping station.
33	M5.6	**Tools and Information Sources for Climate Change Adaptation** ***Wading through the multiple information sources, approaches to climate change adaptation*** The Federal Highway Administration (FHWA) is working to fill the gaps in how engineers can incorporate climate change-related risks into civil infrastructure design relative for transportation agencies. Includes Adaptation Decision-Making Assessment Process (ADAP) and the Climate Change and Extreme Weather Vulnerability Assessment Framework. U.S. Army Corps of Engineers risk management strategies for coastal communities. Climate Adaptation Knowledge Exchange (CAKE). Dilemma: problems are global; solutions are local.
M6: SUSTAINABILITY: THE BUSINESS CASE This section covers how the issues and challenges of sustainability are affecting business and the public sector. What are companies doing? How can they incorporate sustainability policies and practices into their operations and create shareholder value? How has sustainability affected public sector organizations? What is corporate social responsibility and environmental justice?		
34	M6.3	**The Business Case for Sustainability** ***Global sustainability mega-forces and their impacts on business*** Presentation by Bob Willard on how companies can design effective strategies to address sustainability risks while taking advantage of the resulting opportunities.
35	M6.5	**New Belgium Brewing Company and Sustainability** ***A recipe for success or greenwashing on steroids?*** New Belgium Brewing Company and Its commitment to sustainability. Policies and practices. Its culture. Advocacy. Relation to the community. Is this a recipe for success, or is it greenwashing on steroids? Videos of New Belgium news stories, employees and company activities.
36	M6.6	**Sustainability in the Public Sector** ***How are government agencies responding?*** Public sector roles and responsibilities regarding sustainability. What are the policies and programs? What actions are being taken?
37	M6.8	**Corporate Social Responsibility** ***Doing well by doing good*** Corporate Social responsibility (CSR) definition and characteristics. Trends and drivers for CSR. Expansion of an organization's responsibilities. The business case for CSR. Company examples.

38	M6.9	**Finding Environmental Justice** ***Requirements for fair treatment and meaningful involvement for communities*** What is environmental justice? What are its goals? Timeline of civil rights and environmental justice legislation. Relationship to infrastructure in the built environment. Tools for issue analysis.
M7: THE GREAT INFRASTRUCTURE OVERHAUL A changing climate and the subsequent significant changes in environmental conditions means nothing less than a total overhaul in the way we plan, design, construct and operate civil infrastructure. This section covers how various industry sectors are responding: buildings, water, transportation, energy and waste management.		
39	M7.1	**High Performance Buildings** ***Designing for sustainability because it makes economic sense*** High performance buildings: what are they? Impacts of buildings on resources and the environment. Opportunities for performance improvement. Barriers to high performance buildings.
40	M7.2	**Factors in High Performance Building Design** ***Ways to improve the operational performance of buildings*** The elements of high-performance building design. Design approaches. High performance building design examples.
41	M7.3	**Sustainable Urban Water Management** ***Managing water as a system*** Sustainable urban water resource goals. Dealing with urban water infrastructure as a system. Advanced water and wastewater technologies.
42	M7.4	**Making Transportation Systems Effective** ***Providing efficient mobility and access*** The Denver light rail system: my story. Evolution of transportation technology. Importance of transportation systems. Problems in access and mobility. Impacts of transportation systems.
43	M7.6	**Improving Our Energy Systems** ***Addressing climate change and energy security*** U.S. energy: sources, supplies, consumption. Prospects for the future. What will the 21st century bring? Energy as a critical issue for the U.S. and the world. What is required.
44	M7.7	**Pollution and Waste Management** ***How do you throw something away when there is no "away"?*** What is waste? Waste: a systems view. Waste management practices: a comparison. Federal laws governing waste. U.S. waste management infrastructure: a status report.
M8: TOOLS FOR TRANSFORMATION In order to accomplish this overhaul of the built environment, new tools are needed. This section begins with a high-level description of what tools are needed and covers a few in more detail: environmental and social life-cycle assessments, calculating sustainable return on investment, sustainable product design, carbon footprinting.		
45	M8.1	**Tools for Working in a Non-Stationary World** ***A survey of what tools we have vs. what tools we need*** What do we mean by tools? Understanding stakeholder dynamics. Need to start by changing the mindsets of project owners and engineers stuck on stationarity. Tools needed vs. tools currently available. Examples.
46	M8.2	**Environmental Life Cycle Assessments Part 1** ***Four phases and three types*** What is a life cycle assessment (LCA). Stages of analysis. Evolution of LCAs. Conducting an environmental LCA. The four phases: goal and scope definition, inventory analysis, impact assessment and interpretation. Types of LCA's: baseline, comparative, streamlined.
47	M8.3	**Environmental Life Cycle Assessments Part 2** ***LCA inventory analysis*** LCA inventory analysis: process or input-output. Hybrid inventory analysis. Examples. Available LCA software tools.

48	M8.4	**Social Life Cycle Assessments** ***The emerging art of determining a project's impact on society*** Definition of social LCAs. What are social impacts. Differences between environmental LCAs and social LCAs. What aspects to assess. Social "hot spots." Conducting an inventory analysis. Impact assessment and interpretation.
49	M8.5	**Calculating Sustainable Return on Investment (S-ROI)** ***A process for valuing triple bottom line impacts*** Explanation of sustainable return on investment (S-ROI), a triple bottom line valuation framework. A systematic process for calculating benefits and costs of the full range of economic, environmental and social impacts. AIChE videos introduce S-ROI and show how it can be applied.
50	M8.6	**Sustainable Product Design** ***Applying sustainability principles to product design*** Sustainable Product Design using the design of a bicycle as an example, courtesy of Autodesk, Inc. Whole systems design. Light-weighting and materials reduction. Designing for a lifetime. Design for durability, repair and upgrade, disassembly and recycling. Energy use in design. Reducing energy losses in design.
51	M8.7	**Carbon Footprinting** ***Conducting a GHG inventory using the GHG Protocol*** GHG Protocol standards. GHG accounting and reporting principles. Setting operational boundaries. Steps in identifying, calculating and reporting GHG emissions. Sources of information. Tools for calculating your personal carbon footprint.
M9: ASSESSING AND REPORTING PROGRESS This section offers a survey of the tools available for organizations to assess and report on their progress toward sustainable performance improvement. Sustainability audits and rating systems are presented and described. Included are sustainability audits, the Global Reporting Initiative (GRI), greenhouse gas protocols, the Sustainable Development Goals for 2030, LEED, Envision, Business Case Evaluator and AutoCASE.		
52	M9.1	**Making Progress Toward Sustainability** ***Goals, Objectives and Metrics*** Sustainability indicators development timeline. Millennium Development Goals: progress? Sustainability rating systems: products and projects. Overview of the various sustainability measuring and rating systems. Understanding of their purpose and context. Product sustainability measuring and rating systems: Cradle to Cradle Certification, Green Seal, others. Project sustainability measuring and rating systems: LEED, ASPIRE, CEEQUAL, Envision, others.
53	M9.2	**The Sustainable Development Goals for 2030** ***A global plan of action for people, planet and prosperity*** Follow-on program building on the Millennium Development Goals. 17 goals, 169 targets for 2030. Plans for implementation. Data improvements. Relation to climate change. Addressing sustainability at a planetary scale.
54	M9.3	**Performing Sustainability Audits** ***Five types of audits and their application*** What is a sustainability audit? Five types of sustainable audits: their purpose and application.
55	M9.4	**Sustainability Performance Reporting** ***The Global Reporting Initiative (GRI) guidelines*** The Global Reporting Initiative (GRI). Why report on sustainable performance. Evolution of sustainable reporting. The CERES Principles. The GRI guidelines. An evaluation of an organization's contribution to sustainability.
56	M9.5	**Controlling and Reducing Greenhouse Gas Emissions** ***Reporting rules, protocols, cap-and-trade*** GHG protocols and treaties. International GHG emissions reporting. U.S. GHG inventory reporting rules and registries. California's cap and trade program. Rules and targets. Results.

57	M9.6	**Leadership in Energy and Environmental Design (LEED)** ***A sustainability rating system for buildings*** The U.S. Green Building Council. Evolution of green building design. Why buildings? Why LEED? Green building benefits.
58	M9.8	**Envision Sustainable Infrastructure Rating System** ***Recognizing infrastructure projects for their contribution to sustainability*** Envision scope and purpose. Design basis. Organization and structure. System components. Project sustainability assessment, verification and recognition.
59	M9.9	**Tools for Calculating Sustainable ROI** ***Business Case Evaluator and AutoCASE*** Decision support tool for estimating the financial, social and environmental value of infrastructure and building projects. Design alternatives analysis. Data visualization.
M10: SUSTAINABILITY AS A DRIVER FOR INNOVATION This section discusses innovation in sustainability and some of the important innovators. What are the barriers to innovation? Specific examples of innovation: Biomimicry, Industrial Ecology and By-Product Synergy.		
60	M10.1	**Innovation and Sustainable Development** ***Changing operating conditions as a disruptive anomaly*** What is innovation? Barriers to innovation in sustainable design. The innovator's dilemma. The eco-innovator's dilemma. The engineer's dilemma. Changing operating conditions as a disruptive anomaly. Thomas Kuhn and Bill McKibben. The disruptive innovators. Examples.
61	M10.2	**Biomimicry** ***Innovation inspired by living systems*** Biomimicry: definition, taxonomy. Nature's design criteria. Examples: products, process and infrastructure designs based on designs from nature**.**
62	M10.3	**Industrial Ecology and By-Product Synergy** ***Innovations in industry*** Industrial ecology definition. Evolution of industrial systems: Types I, II and III. Kalundborg Park. By-product Synergy (BPS): history, example applications, process.
M11: SUSTAINABLE PROJECT MANAGEMENT This section presents a process for delivering climate-safe and sustainable infrastructure projects. Seven phases. Using Phase-Gates. Application of Dynamic Adaptive Planning (DAP) and Dynamic Adaptive Policy Planning (DAPP) to civil infrastructure project delivery. How some project owners are addressing sustainability and non-stationarity. Tailored resiliency for lower Manhattan: barriers to flooding that serve multiple purposes. Resist, delay, store and discharge: a strategy for the city of Hoboken, New Jersey. The Prairie Waters Project: finding a new sustainable water source for the City of Aurora, Colorado. An application of DAPP to address resource scarcity in southern Portugal.		
63	M11.1	**Delivering Climate-Resilient and Sustainable Infrastructure: An Overview** ***How this approach is different from normal infrastructure project delivery.*** Project objectives and context. Normal project delivery vs. sustainable and climate-safe project delivery. Approaches for dealing with Level 4 uncertainty. Application of Dynamic Adaptive Planning (DAP) to civil infrastructure projects. Why DAP. Barriers to using DAP.
64	M11.2	**Delivering Climate-Resilient and Sustainable Infrastructure: DAP Process Summary** ***Introducing DAP and setting the stage for a DAP infrastructure project.*** Project life cycle: seven phases. Project life cycle summary, highlighting the DAP elements. First phase: Project Planning. Setting the stage. Establishing goals and objectives. Identifying constraints. Defining project success. Creating an options set.
65	M11.3	**Delivering Climate-Resilient and Sustainable Infrastructure: Project Understanding** ***Converting options into a viable project alternative*** Determining conditions for success. Assembling the basic plan. Devising, evaluating and selecting the project alternative. Climate stressor risk reduction. Increasing the robustness of the basic plan. Actions to address vulnerabilities and opportunities: mitigating, hedging, seizing, shaping.

66	M11.4	**Delivering Climate-Resilient and Sustainable Infrastructure: Definition, Design, Completion** ***Completing the project and monitoring for change.*** Setting up the monitoring systems for adaptation, validity of assumptions. Setting signposts and triggers. Preparing trigger responses. Moving to cost-efficient project delivery. Operations and maintenance. Monitoring for adaptation. Monitoring for validity of project assumptions. Project end of life: demolish, recycle, repurpose.
67	M11.5	**Sustainable Design for a Changing Operating Environment, Project Examples** ***How project owners are addressing sustainability and non-stationarity*** Examples of how cities are addressing the impacts of non-stationarity. Tailored resiliency for lower Manhattan. Still just a big wall! Barriers to flooding that serve multiple purposes. Resist, delay, store and discharge: a strategy for the city of Hoboken, New Jersey. The Prairie Waters Project: finding a new sustainable water source for the City of Aurora, Colorado.
68	M11.6	**Dynamic Adaptive Policy Planning: Introduction** ***Pathways: Terminology, Types and Characteristics*** Dynamic Adaptive Planning (DAP) vs. Dynamic Adaptive Policy Planning (DAPP): what are the differences? DAPP terminology. Pathways for achieving objectives, success. Types of pathways: Physical Alterations, Operational Adjustments, Governing Policies. Pathway characteristics: effectiveness, robustness, resilience.
69	M11.7	**Dynamic Adaptive Policy Planning Methodology: Part 1** ***Steps 1 through 4 in Dynamic Adaptive Policy Planning*** The 10 steps in Dynamic Adaptive Policy Planning. Description of steps 1 through 4. Describe the problem, analyze the problem, determine possible adaptation pathways, evaluate and reassess pathways.
70	M11.8	**Dynamic Adaptive Policy Planning Methodology: Part 2** ***Steps 5 through 10 in Dynamic Adaptive Policy Planning*** Description of steps 5 through 10. Assemble pathways into routes, select the most promising routes, improve pathway robustness and resilience, select a dynamic adaptive plan, implement the plan, monitor and respond.
71	M11.9	**Dynamic Adaptive Policy Planning Application** ***Addressing Water Scarcity in Southern Portugal*** Using Dynamic Adaptive Policy Planning and hydrological modeling to co-create water resource adaptation policies in the Algarve region of Portugal. Water resources are getting scarce. Water exploitation is expected to increase unless changes are made. Stakeholders explore and evaluate various adaptation options and develop a plan using DAPP.
M12: RESILIENT, SUSTAINABLE CITIES This section covers the importance of cities and what it will take to create a "sustainable" city. What are the challenges? What strategies have cities used to leverage sustainability for growth and development?		
72	M12.1	**Creating Sustainable Cities** ***The city as an efficient form of human habitat*** What is a city? Increasing global urbanization. Importance of cities. Elements of a sustainable city.
73	M12.2	**Becoming a Sustainable City** ***The four challenges*** Four challenges in creating sustainable cities: technical, financial, organizational and public policy.
74	M12.3	**Green City Development** ***Sectorial strategies for sustainable growth and development*** New opportunities for cities created by a shift to sustainability. Sectorial strategies: How cities are taking advantage of these opportunities. Types of sectorial strategies. City response to climate change. Ranking cities based on sustainability criteria.
M13: Course Wrap-up Close out of the course. Thank you for participating!		

75	M13.1	**Course Wrap-up** ***Brief summary of the course*** Takeaways from the course. The B.H.A.G. revisited. Thanks! Goodbye and good luck!