CEE 107R/207R: E^3: Extreme Energy Efficiency
3 Units

Winter Quarter 2021, Remote
1/11/21 - 3/19/21

Wednesdays, 5:30PM - 8:20PM PT
Location: Zoom

Hosted by Amory B. Lovins, https://rmi.org/people/amory-lovins/
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Course Description

This course will investigate integrative design, revealing and exploiting connections between parts of a system to achieve far more than the sum of their individual benefits. Integrative design uses and artfully combines, sequences, and times *fewer*, *simpler* technologies, achieving greater savings at lower cost and creating *increasing* returns rather than *diminishing* returns. The techniques, principles, and modes of thinking involved in integrative design can offer levels of energy and resource efficiency far greater than generally expected or achieved in the mobility, buildings,

industrial, and electricity sectors. The emphasis of the course will be on real-world implementation of these techniques and their diverse, often disruptive implications. Students will learn this innovative approach to design through a combination of lectures, workshops, problem-solving sessions, and presentations from Rocky Mountain Institute's cofounder Amory Lovins and his colleagues, who have developed a unique suite of design techniques and principles that apply whole-systems thinking to achieve extreme—even order-of-magnitude higher—energy and resource efficiency. This approach to optimizing the whole system for multiple benefits, rather than isolated components for single benefits, is known as Factor 10 Engineering, or 10xE. It has yielded enormous energy savings, better performance, and lower capital cost across diverse engineering disciplines and applications.

This course includes a mix of keynote lectures, guest lectures, interactive Puzzlers, and exercises synthesizing integrative design. Before each class on Wednesday, students are expected to complete the readings, watch the pre-recorded lecture (if applicable), and write their journal entry. Each class will begin with reflection and inquiry with Amory Lovins and Dr. Holmes Hummel based on your journal entries. The remainder of class time will be for interactive Puzzlers and/or exercises followed by presentations and group discussions. At least 5 classes will be dedicated almost entirely to interactive Puzzlers. Some classes will include live lectures from Amory Lovins and/or guest lectures.

Stanford students from all disciplines and of all levels are eligible to participate. This topic requires imaginative, whole-systems thinking, and the class will benefit from the perspectives of students from all backgrounds and with a wide range of interests. **Due to the COVID-19 pandemic and shelter-in-place, the Winter 2021 course will be held online via Zoom.**

Description of Rocky Mountain Institute

Rocky Mountain Institute (RMI), founded in 1982, is an independent, nonprofit, entrepreneurial think-and-do tank that transforms global energy use to create a clean, prosperous, and secure low-carbon future. It engages businesses, communities, institutions, and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. The organization's ~200 staff work in Basalt and Boulder, Colorado; New York City; Washington, D.C.; Oakland, California; and Beijing.

RMI has a 38-year record of fundamental innovation in energy efficiency and renewables spanning all sectors and most applications. Its recent international accomplishments include co-leading *Reinventing Fire: China* (a roadmap for radical resource efficiency and economic growth that strongly informed China's 13th Five Year Plan) and *India Leaps Ahead* (an electric and IT-driven reframing of personal mobility for the Government of India), and helping Rwanda design a rise in electrification from 25% to 75% at $1 billion lower cost ($20 million a year immediately). In the U.S., RMI is scaling up major efficiency gains in buildings, testing new mobility models in Austin, slashing solar power costs, and helping create the next electricity industry.

To learn more about RMI's wide ranging work, please visit www.rmi.org. RMI's blog is updated frequently to reflect the Institute's current projects and perspectives.

Course objectives for CEE 107R/207R are:

- ✓ To engage students with Factor 10 Engineering—the problem-solving design practice developed and long successfully implemented by Rocky Mountain Institute to deliver real-world examples of profitable resource efficiency
- ✓ To teach optimization of whole systems to capture multiple benefits and increasing returns from single expenditures
- ✓ To apply consistent methods and processes while moving briskly through a wide range of design challenges
- ✓ To develop critical thinking skills and apply newly learned concepts in afternoon workshops and small-group exercises with different topical themes each day
- ✓ To provide direct professional development for students in a wide variety of fields and encourage an entrepreneurial spirit for problem-redefining and -solving
- ✓ To promote networking and collaboration among Stanford students with shared interests across different disciplines, as well as connecting them with Rocky Mountain Institute staff

Upon completion of CEE 107R/207R, students should be able to:

- Innovatively think about and apply advanced energy efficiency
- Integrate Factor 10 Engineering approaches into projects across a variety of disciplines, in both future academic studies and career work
- Raise challenges and address opportunities at the nexus of engineering and economics
- Identify ways to apply integrative design in developing countries
- Rethink tough problems not by shrinking their scope but by enlarging their boundaries
- Consider the role of integrative design and whole-system thinking in engineering and design classes taught at Stanford

The course is predicated on the assumption that many, if not all, important issues in efficiency require substantive understanding of diverse and multiple disciplines. Thus the concepts, readings, and class assignments in the course will examine and cover theories, models, and ideas from a variety of economic sectors and real-world applications. Please be ready to bring your own unique perspectives, insights, and experiences to class assignments and discussion.

Course Requirements

Each week, students are expected to:

- Complete required readings in advance of class
- Watch pre-recorded lectures (if applicable) in advance of class
- Attend all class activities (see additional information on attendance, page 8)
- Actively participate in discussions and activities

- Complete in-class Puzzlers (described on page 6-7)
- Submit journal entry following class (described on page 6)

There will be no midterm or final for this class. Students will complete a midterm report on applied integrative design (described on page 5).

Grading

A final letter grade for the class will be awarded for each student, based on :

Attendance/Participation	30%
Journal Entries	15%
Weekly Puzzlers	35%
Applied Integrative Design Report	20%

Please note that a substantial percentage of the final grade is attendance and participation. If you have difficulty speaking in class / group settings, please meet with one of the TAs as early in the course as possible to discuss your situation. Participation will be evaluated on an individual basis by the Teaching Staff and will value *quality* of contribution as much as (and in some cases more than) *quantity*. **If you have challenging circumstances that may affect attendance and/or participation because of COVID-19 (in another time zone, have become a caregiver for someone in your family, taking care of kids at home, etc.), please reach out to the teaching staff and we will be accommodating and flexible!**

Course Units

The following tentative topic list is subject to change.

Focus 1: Buildings

- Conventional vs. integrative design
- Passive thermal comfort in cold, hot, and humid climates
- Illumination
- Water heating
- Appliances and other loads
- Design, construction, commissioning, improvement, and adaptation
- Real-estate implications

Focus 2: Mobility

- Radical light-duty vehicle efficiency
- Vehicles and mobility demand
- Electric and alternative-fueled vehicles
- Shared mobility systems
- Connected mobility systems
- Autonomous vehicles
- Business strategy

- Heavy-vehicle efficiency and logistics

Focus 3: Industry
- Purpose and design intent
- Fluid-handling and drivesystems
- Process heat
- Heavy-industry examples
- Technology-industry examples
- Industrial systems

Focus 4: Electricity
- Implications for demand and business model
- Comprehensive disruptions
- Grid and generation right-sizing
- The supply-side revolution
- Cost-effective integration of variable renewables
- Transition paths

Focus 5: Disruptive Energy Futures
- Market adoption of energy efficiency, renewables, and integrative design
- Pace of disruption
- National-level strategies for rapid, cost-effective decarbonization and energy security
- Turning barriers into business opportunities
- Profitable climate protection through energy savings and natural-systems carbon removal

Activity and Assignment Descriptions

Applied Integrative Design Report
Must be submitted on Canvas by ***Wednesday, Feb 17, 11:59pm PT***
Students will write a report on how integrative design could be applied to provide energy savings, better performance, and lower capital cost to a system on the Stanford campus or a larger world system. Students will apply the concepts of whole-systems thinking and at least 3 of the 12 pillars of integrative design to explore how your chosen energy system can be improved (energy savings, lower costs, etc.). We are looking for reports that apply these concepts, instead of merely restating them. This report will be 1500 words minimum, 2500 words maximum. Graphs, charts, and tables are required. Please cite all sources used, including any sources used outside of the required and recommended readings. This assignment is intentionally flexible in order to allow students to explore integrative design through a practical lens. There is no "right" topic, though more complicated systems do make for a more engaging assessment!

Journal Entries
Must be submitted on Canvas ***every Tuesday by 5:00pm PT***
Each student will submit weekly journal entries on Canvas. Each (900 words maximum) will compile reactions, insights, reflections, responses, questions, and implications from the previous

day's class discussion, as well as, incorporate forward-thinking thoughts, questions and inquiries stemming from pre-lecture material for the next week's class This assignment is intentionally flexible in order to serve as a forum for individual exploration of the concepts presented in class on the day prior. The goal of this assignment is to encourage reflective and critical inquiry. The questions and inquiries raised about the upcoming material will be reviewed before each class to foster the starting discussion with Dr. Lovins and Dr. Hummel.

Possible questions to help frame lessons learned:

- How does what I learned connect with my background, interests, skills, and professional and personal aspirations?
- What are some personal "aha" moments? How can I best share these insights with others?
- What critical challenges would I raise to the material presented? What real-world, practical obstacles do I foresee? What are my suggestions for overcoming them?
- If I am doubtful about any of what I just learned, how could I test its validity?
- What are some critical (small or large) next steps?
- What are some direct and indirect implications for my own education or the education of others?
- What should Stanford be doing to help address these issues? What should I be doing?

Students will be graded in the following manner:

- 0-10 points: Unacceptable. Missing, late, or very poor quality assignment. Poor quality indicated by meager summary of the topic and issue and insufficient style/grammar/formatting/etc.; lack of overall effort evident. Does not incorporate assigned readings/videos.
- 10-20 points: Acceptable. Descriptive, but little contribution beyond summarizing facts from lecture, session, and other sources. Some personal points of view/analysis. Average writing skills (grammar, form, flow, style). Some thought given to assigned readings/videos, but minimal reflection/inquiry.
- 20-30 points: Excellent. Went beyond re-stating facts by using critical analysis. Used insightful arguments and top-level writing skills (grammar, form, flow, style). Uses both learned material and assigned readings/videos for the next class to shape insights and inquiries. Poses forward-thinking questions to the material.

In-Class Puzzler (Group Activity)

Each workshop session is intended to be an exercise in integrative problem solving and out-of-the-box thinking (there is no box!), as well as insightful framing, estimating, and research. The ultimate aim is for students to gain first-hand experience applying RMI's problem-solving methods. Work must cite any website or other supporting material used.

In-Class Puzzler Write-Up

Each group will write up and turn in the main take-aways from the Puzzler, e.g. context, challenge, solution, and conclusions or implications. Write-up will be a document of no less than 300 words to be submitted via Canvas program. Answers will be graded on: 1) Application of whole-systems principles (50%), 2) creative analysis (20%), and 3) breadth and depth of response (30%).

Puzzler Presentations and Group Discussion

After the Puzzlers, each group will have a chance to present their solution, and bring up issues, questions, or ideas they encountered during the day's work. This will give students the benefit of seeing others' solutions, stimulating a lively whole-class or smaller group discussions. We will also discuss next potential steps for the subject area.

Readings

Below is a selected list of publications by Amory Lovins that are the most appropriate background readings for the course. Recommended readings will be helpful in completing the Puzzlers and other assignments. This is a reference reading list and will be trickled throughout the quarter depending on weekly topic. **A more specific course schedule will be posted ahead of the quarter.**

Required:

1. Lovins, A.B. (2012). "A farewell to fossil fuels: Answering the energy challenge." *Foreign Affairs*. http://www.rmi.org/Knowledge-Center/Library/2012-01_FarewellToFossilFuels
2. Lovins, A. B., Lovins, L. H., & Hawken, P. (1999). "A roadmap for natural capitalism." https://rmi.org/insight/roadmap-for-natural-capitalism/
3. Lovins, A.B. (2018). "How big is the energy efficiency resource?" *Envtl Res Ltrs* **13**(9):1–17, https://doi.org/10.1088/1748-9326/aad965
4. Lovins, A. B., & Lovins, L. H. (1997). "Climate: Making Sense *and* Making Money." https://rmi.org/wp-content/uploads/2017/05/RMI_Document_Repository_Public-Reprts_C97-13_ClimateMSMM.pdf
    a. *Read pages 11-20 (article numbering, not PDF index); skim the rest of the article*
5. Autodesk Sustainability Workshop. "Whole Systems Design: Introduction to Life Cycle Thinking." https://www.youtube.com/watch?v=7mC9xaJC2dQ
6. 3P Theory (3 November 2019). "Revisiting the Integrative Design Process." https://www.stitcher.com/podcast/3p-theory/e/65031820
    a. *Listen to **start–12:20** and **21:20–end***

Recommended:

Books:

1. *Reinventing Fire*, Amory Lovins and Rocky Mountain Institute. Published by Chelsea Green (White River Jct, VT). Oct 2011. Summary chapters and details included at https://www.rmi.org/insights/reinventing-fire/. The entire book will be helpful, in hard copy or (Amory suggests) the Google Books version, which handles the intensive graphics and layout more gracefully than the Kindle version.
2. *Natural Capitalism: Creating the Next Industrial Revolution*, P. Hawken, A.B. and L.H. Lovins, Little Brown (NY) and Earthscan (London), 1999, 415 pp., posted free as tediously downloadable-chapter-by-chapter PDFs at www.natcap.org

Articles:

1. Meadows, D. H. (1997). "Places to intervene in a system." *Whole Earth*, 2(91). https://www.bfi.org/sites/default/files/attachments/pages/PlacesInterveneSystem-Meadows.pdf
2. Lovins, A.B. (2005). "Energy end-use efficiency." Snowmass, CO: Rocky Mountain Institute. http://www.rmi.org/Knowledge-Center/Library/E05-16_EnergyEndUseEfficiency

Videos:

1. Meadows, Donella. "Sustainable Systems." Lecture (1 of 4). https://www.youtube.com/watch?v=HMmChiLZZHg
2. Meadows, Donella. "Sustainable Systems." Lecture (2 of 4). https://www.youtube.com/watch?v=HuIoego-xVc
3. Meadows, Donella. "Sustainable Systems." Lecture (3 of 4). https://www.youtube.com/watch?v=j-k5oSlgIbA
4. Meadows, Donella. "Sustainable Systems." Lecture (4 of 4). https://www.youtube.com/watch?v=d9Lfp8SQ6rc

Attendance / Course Policies

- Attendance is mandatory at all scheduled class activities. If you have special needs, or are required to miss an event or scheduled activity, please let your TAs know as soon as possible. Because we understand that conflicts do occur, you are allowed one excused absence with completion of a make-up assignment during the quarter for a valid conflict (to a single scheduled activity) without consequence to your grade. An additional absence (over the one allowable) will result in a 5% reduction to your grade with a maximum of a 20% reduction.In addition, failure to attend regularly will result in grade losses for participation, journal entries, and Puzzlers. In other words, attend the seminar sessions! **If you have challenging circumstances that may affect attendance and/or participation because of COVID-19 (in another time zone, have become a caregiver for someone in your family, taking care of kids at home, etc.), please reach out to the teaching staff and we will be accommodating and flexible!**
- Students are reminded that they are expected to comply with the Stanford Honor Code and Fundamental Standard at all times. Information on these policies is available at https://communitystandards.stanford.edu/student-conduct-process/honor-code-and-fundamental-standard.
- A course of this density requires your full attention. Distracting and extraneous activities (Internet surfing, non-emergency messaging and emailing, etc.) during lectures and class are strongly discouraged and are discourteous. **We understand this may be an urge that is difficult to fight while the course is delivered online, but please respect the time and effort that has gone into this course to still offer it. Please stay as focused as you can – the more students we have participating and engaging, the more camaraderie and community we will feel and share during these strange pandemic times.**

Website and Communications

Our class website can be found on the Canvas system.

Our class will have an email list that the TAs will use for mass communication. This year, we are also using Slack, a messenger app. Slack will make it easier for Puzzler Groups to communicate with one another on one mass platform, as well as providing a forum for students to chat about topics both inside and outside the classroom. You should have an invitation from Slack to join this channel if you are registered for the course—check your Spam folder if you do not see it. If you have questions, please contact one of the TAs.

We will be using Zoom and its breakout rooms for the class each day. We will be communicating over Slack for updates on timing. Please download Slack onto your desktop and turn on all notifications.