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

Spring Break 2019

16:00 MT Sunday March 24 to 14:00 MT Friday March 29, 2019

Location: Rocky Mountain Institute Innovation Center, 22830 Two Rivers Road, Basalt, CO 81621

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

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Course Description

This course will investigate integrative design. These techniques, principles, and modes of thinking 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. Undergraduate and graduate students from all disciplines are eligible to apply. 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.

What is integrative design? Integrative design reveals and exploits connections between parts of a system to achieve far more than the sum of their individual benefits. It makes the parts work with each other, not against each other. Integrative designers optimize the performance of buildings, vehicles, machines, and industrial processes by collaborating in diverse teams to understand how the parts work together as a system, and then use this knowledge to harness synergies that increase efficiency, reduce waste and energy use, and improve functionality. These engineered systems similarly interact with larger systems (e.g., communities, cities, economies, industrial value webs, ecosystems), which interact with each other. The more complete the design integration—spanning space, time, and disciplines—the better the result. Rather than saving more energy by using *more*, *costlier* technologies, 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.

Many companies and industries are already using integrative design to achieve radical resource efficiency. For example, Interface, Inc. applied integrative design principles to its Dutch carpet factory. More-efficient pumps and motors were obvious energy-efficiency measures. But integrative design achieved far greater savings by making pipes fat, short, and straight. This design solution cut pipe friction by at least 86%, shrinking the pumps and motors, and cutting both capital and operating costs.

Over the past few decades, Rocky Mountain Institute's cofounder Amory Lovins and his colleagues 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.

The course will address barriers and strategies for implementing Factor 10 Engineering principles, including implications for energy supply and demand, business interests, climate, global development, and national security. An overarching theme will govern each day. The five themes are: buildings, mobility, industry, electricity, and cross-sectoral implications.

Stanford students from all disciplines and of all levels are eligible to participate. The course covers hotel accomodations for Saturday, March 24th through Friday, March 30th (check-out is Friday morning) and meals from Sunday dinner through Friday lunch.

Students are responsible for arranging and paying for their own transportation to the event. Some suggestions for travel options are listed on page 4.

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.; and Beijing.

RMI has a 37-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 wideranging 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 student is expected to:

- Complete required readings
- Attend all class activities (see additional information on attendance, page 10)
- Actively participate in discussions and activities
- Maintain a class journal (four entries)
- Complete Daily Puzzlers (described on pages 8–9)
- Complete planned assignment on applied integrative design prior to Spring Break meeting

Ancillary Information for Visiting the Roaring Fork Valley

Rocky Mountain Institute's Innovation Center—a net-positive-energy passive building with no boilers, furnaces, or chillers—is located in Western Colorado's Roaring Fork Valley, home to the towns of Aspen, Basalt, Carbondale, and Glenwood Springs. Students who wish to take advantage of skiing, hiking, or other activities may want to add days onto their trip, either before or after the course, because free time during the course will be limited. The RMI class TAs are happy to provide recommendations for places to visit in the Valley, and highly recommend spending an extra day or two to explore if possible. Students will be responsible for their own accomodations and food outside the course's duration. The course does not cover the cost of transportation to/from Basalt, Colorado.

Students will be staying at the **Basalt Mountain Inn**:
220 Midland Ave, Basalt, CO 81621
Phone: (970) 927-4747
http://www.basaltmountaininn.com/

Transportation Suggestions:

If you have questions about transportation, please contact Diana Ginnebaugh (moongdes@stanford.edu) and she can provide help/suggestions/carpooling groups, etc.

- Students should try to **arrive on Saturday**, to allow time for acclimation to high altitude (Basalt is at about 6,600 ft/2,000 m elevation, Aspen 8,000 ft/2,400 m). Accomodation is available starting on Saturday evening. Arriving early will also ensure that students arrive on time for the course's opening session (Sunday, 1700 / 5:00 pm Mountain Time), even if mountain weather disrupts travel plans.
- Students may **fly directly into Aspen airport** and take the convenient bus system ($4 one way) from there to Basalt Downtown (about 30 minutes' bus time). Be aware that

flying direct into Aspen is expensive, and flights can experience delays, often by hours or even a day due to inclement weather. Take this possibility into account in your planning.

- Students may **fly into Denver Airport**, which is typically the cheapest flight option (~$180 roundtrip from SFO, if booked early). From there, they may either rent a car to travel the ~3.5 hours (in good weather) to Basalt or may take a Colorado Mountain Express direct shuttle van (approximately $120 one-way, though group deals are possible). We recommend using a car with appropriate snow tires, AWD, or chains, as not doing so can lead to a fine when crossing high passes on I-70 during poor weather (beyond the accident potential). Alternatively, students may take a Bustang or Greyhound (~$30) bus to Glenwood Springs, CO, which has a convenient bus system directly to Basalt Downtown (~40 minutes' bus time and $4 one way). Accessing the Denver Union bus station will require a short subway ride from the Denver Airport. This option is typically the cheapest (but slowest) way of getting to Basalt from Denver.
- Students may **fly into Grand Junction, CO**, whose airport seldom experiences weather delays. From there, a car rental is the best option (bus station is not easily accessible from airport) for getting to Basalt, CO (~2 hours' drive). We suggest sharing a vehicle with other students for maximum efficiency.
- Students may **drive from Palo Alto to Basalt, CO.** This drive takes ~17 hours (normally two days' driving time). There is more than one route, but due to potential winter weather, we recommend taking the southern route through Las Vegas and then up to I-70. Again, we suggest carpooling with other students for transport efficiency. We recommend using a car with appropriate snow tires, AWD, or chains, and these may be required on some high passes in California or Nevada.
- Students may **take Amtrak or Greyhound into Glenwood Springs, CO**, which has a convenient bus system directly to Basalt Downtown (~40 minutes' bus time and $4 one way).

Health and Comfort Suggestions:

- Basalt, CO is 6,600 feet above sea level (ski mountains in Aspen can reach 11,500 feet). Students should expect to **increase their water intake** by 2–3 liters per day, and be prepared to feel dry. Some may experience shortness of breath, and should **remain alert for symptoms of altitude sickness.**
- The sun is strong and actinic, so **bring a hat and sunscreen**.
- During winter, **temperatures can reach –10˚F / –23˚C**. Students should come prepared for cold weather and potential snow (e.g., warm jackets and layers, waterproof boots). Opportunities for walks along the river and woods with RMI staff will probably have snow on the paths, so students should **plan on wearing boots** for daily sessions.

Recreation Suggestions:

- For students looking to spend additional time in the area, activities include downhill skiing, cross-country skiing, snowshoeing, hiking, and visiting the several wild or developed hotsprings. Numerous concerts, operas, ballets, and other cultural activities are also available.
- Students wishing to ski may want to purchase a lift ticket in advance (available here), which gives a discount on multi-day tickets. Many ski shops in the area offer equipment rentals.

- Hotels and AirBnBs are numerous in the area and should be booked as quickly as possible. Numerous residents in the valley also promote "couch surfing" and similar options outside the scope of this course's arrangements.
- A low-cost bus rapid transit system is available throughout the Roaring Fork Valley. This bus either delivers directly to major destinations, or connects to free shuttles that do so.

Course Units

The following tentative topic list is subject to change.
Note: The evening of Sunday, March 24, students will be expected at a welcome dinner, lecture, and a tour of Amory Lovins's nearby home, beginning at 1600 / 4 PM at RMI's superefficient, integratively designed Innovation Center. Transportation will be provided to/from Amory's home.

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

General Daily Activities and Assignments (example schedule, may be subject to small changes depending on material and lecture timing)

Breakfast: (8:30am–9:30am starting Monday)

- Breakfast provided at Basalt Mountain Inn, with coffee and tea available at RMI
- Opportunity to speak with RMI professionals about their work fields, projects, and programs
- Students can come anytime during this window, but please be done eating and ready for lecture at 9:30am

Morning Sessions (9:30am)

- Submit previous day's journal entry by start of class
- Morning lectures by Amory ~ 60 min
- Q&A with Amory ~ 30 min
- RMI Program Leader Lecture and Q&A ~ 60 min
- Introduction to afternoon puzzler activity ~ 15 min

Lunch (~12:45pm)

- Lunch provided at Rocky Mountain Institute Innovation Center
- Group walks and discussion sessions along river/town with Amory Lovins and other RMI leaders (one small group with Amory per day)

Afternoon Sessions (~1:45pm–6:00pm)

- Daily Puzzler (~5-person group activity with RMI staff and TA assistance) ~ 2 h
- Turn in Puzzler write-up
- Groups present puzzlers to the class and discuss open questions and ideas ~ 1 h
- Evening lecture, normally by Amory ~ 30–60 min
- No afternoon session on Friday

Dinner (6:30pm)

- Dinner provided at RMI Innovation Center (Sunday evening starting at 5:00)
- Review agenda for the next day

Activity and Assignment Descriptions

Applied Integrative Design Report

Will be submitted on Canvas prior to spring break course on Monday, March 11th, 11:59pm

Using their initial impression of integrative design gleaned from required readings, recommended readings, and Dr. Amory Lovins's lecture on February 19th, each student will write a report how intergrative 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. This report will be 1500 words minimum, 2500 words maximum. Graphs, charts, and tables are encouraged. Please cite all sources used, including any sources used out 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 by 9:30am Tuesday, Wednesday, Thursday, Friday

Each student will write a daily journal submission (750 words maximum) compiling reactions, insights, responses, questions, and implications from the previous day's class discussion. 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.

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 point: 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.
- 1 point: 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).
- 2 points: Excellent. Went beyond re-stating facts by using critical analysis. Used insightful arguments and top-level writing skills (grammar, form, flow, style).

Daily Puzzler (Group Activity)

~1:45pm daily
Each workshop session is intended to be a relatively short 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.

Daily Puzzler Write-Up

Due between 3 and 4pm daily—see schedule below for precise timing
Each group will write up and turn in the main take-aways from the Daily 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

~4pm daily
After the Daily 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 discussion. We will also discuss next potential steps for the subject area.

Grading

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

Attendance	20%
Participation	25%
Journal assignments (4)	15%
Daily Puzzlers (4)	20%
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*.

Readings

Below is a selected list of publications by Amory Lovins that are most appropriate background readings for the course. Recommended readings will be helpful in completing the puzzlers and other assignments. It is expected that the required readings will be completed prior to the February 19th lecture for context in integrative design. Copies of some of the recommended

books will likely be available for interested students to borrow at the Innovation Center; ask one of the RMI course assistants upon arrival in Basalt if interested.

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

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 TA know as soon as possible. Because we understand that conflicts do occur, you are allowed one absence over the course of the week 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. Thus if you miss four or more events you will receive a “0” for the attendance portion of your overall grade. In addition, failure to attend regularly will result in grade losses for participation, journal entries, and daily puzzlers. In other words, attend the seminar sessions!
- 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, are discourteous, and may reduce your grade.

Website and email list

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. We will also try to provide group email lists for each working group (which students may use) to assist with communication throughout the week. 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 provding a forum for students to chat about topics both inside and outside the classroom. Join link here:
https://join.slack.com/t/e3rmi2019/shared_invite/enQtNTI0NjUzNTE2NjkzLTZjODQ1M2Q2ZTZhZWRjZmVjNDU1YjUzMWMzYWMxYjM3NDJhZDdiOWE3MWVjZTQ0NjQxMGY0ZWI0N2NjZmE3Njg

For students participating, a “bio book” will be provided of the TAs, RMI staff, and students. Students may elect to provide their information and email in this document.